OCTOBER 1990

HIGH RESOLUTION MICROWAVE SPECTROMETER SOUNDER (HIMSS)

FINAL REPORT

VOLUME 1, BOOK 1
EXECUTIVE SUMMARY AND TECHNICAL

CONTRACT NO. NAS8-38175

SUBMITTED TO:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER

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FOREWORD

This High Resolution Spectrometer Sounder Final Report has been prepared for Marshall Space Flight Center, under contract no. NAS8-38175, and it is submitted in compliance with the contract deliverables, data item 5. This report also includes the preliminary program plans, CEI specification and Instrument interface description document.

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ACRONYMS

ABM	Active balancing mechanism
AO	Announcement of opportunity
ASIC	Application specific integrated circuit
AUSSAT	Australian satellite built by Hughes
BAPTA	Bearing and power transfer assembly
BCE	BAPTA control electronics
BDU	Bus data unit
BSR	Bus select relay
CDR	Critical design review
CPT	Comprehensive performance test
dB	deciBell
DMSP	Defense Meteorological Satellite Program
Eos	Earth observing system
EMC	Electromagnetic compatibility
EMI	Electromagnetic interference
ECRA	Electrical contact ring assembly
FET	Field effect transistor
FFT	Full functional test
GE	General Electric
GHz	Giga Hertz
GIIS	General instrument interface specification
GMS	Geostationary Meteorological Satellite
GSE	Ground support equipment
HIMSS	High resolution microwave spectrometer sounder
HTR	Heater
ICWG	Interface control working group
in	Inch
K	Kelvin
Kg	Kilogram
Km	Kilometer
KRTR	Kit requisition and traceability record
lbm	pound
LFT	Limited functional test
LO	Local oscillator
LNA	Low noise amplifier
m	Meter
Mbps	Mega bits per second
MHz	Mega Hertz
MIC	Multi-layer integrated circuit
MIP	Master index pulse
MMB	Multi mission bus
MRR	Manufacturing readiness review
mS	milli-second
MSFC	Marshall Space Flight Center
MWA	Momentum wheel assembly
N	Newton
N/A	Not applicable

OMT	Ortho-mode transducer
PROM	Programmable read-only memory
PDR	Preliminary design review
PRR	Preliminary requirements review
PQR	Program quality requirements
PS	Power supply
PSP	Payload support plate
PSS	Payload support structure
PWB	Printed wiring board
RCVR,REC	Receiver
RDA	Reflector deployment actuator
RF	Radio frequency
rms	Root mean square
rpm	Revolutions per minute
QCHR	Quality control history record
S/C	Spacecraft
SCG	Space and Communications Group
SCU	Speed control unit
SIC	Standard interface connector
SOW	Statement of work
SPU	Signal processing unit
SSM/I	Special sensor microwave/imager
SST	Sea surface temperature
T	Temperature
TBD	To be determined
TBR	To be resolved/reviewed
TV	Thermal vacuum
UHF	Ultra high frequency
V	Volts
VDA	Vapor deposited aluminum
VLSI	Very large scale integration
W	Watts

1.0 INTRODUCTION AND EXECUTIVE SUMMARY

1.1 DEFINITION PHASE STUDY OBJECTIVES

During the HIMSS definition phase study, Hughes has developed a preliminary design for a conically scanning, total power radiometer, compatible until the Eos mission objectives. The level of design detail is sufficient to support a budgetary cost estimate. This budgetary cost estimate is for 3 flight instruments and a complete set of spares. The knowledge of the level of technical readiness, as well as a comprehensive schedule, are important components in the accuracy of the budgetary cost estimate.

As part of the study, Hughes has prepared some preliminary program plans. They are: Performance Assurance Plan, Configuration Management Plan, Software Implementation Plan, Calibration Management Plan, Verification Plan, Contamination Control Plan and Spares Plan.

1.2 HIMSS INSTRUMENT OVERVIEW

The HIMSS instrument defined during the Phase B study meets all science requirements. Careful coordination throughout the definition phase study with Marshall Space Flight Center (MSFC) and with Remote Sensing Systems, which is developing preliminary architectures for the algorithms, resulted in an optimally allocated instrument and algorithm requirements.

In order to reduce instrument development and production risks, the HIMSS instrument concept is derived from the architecture of the Special Sensor Microwave/Imager (SSM/I) built for the Defense Meteorological Satellite Program (DMSP). Much of the actual hardware is taken or readily modified from SSM/I hardware. The management approach for the HIMSS program also benefits from our experience on the SSM/I Program.

The HIMSS instrument provides superior performance relative to its predecessor SSM/I instrument in several respects: principally higher spatial resolution, better temperature resolution, and additional channels at 6.63 and 10.65 GHz to provide sea surface temperature and roughness data.

HIMSS, like its predecessor, SSM/I, is a mechanically scanning radiometer. Mechanical scanning provides more accurate instrument calibration, since warm and cold loads are passively sampled during each scan period through the same path as the science data.

The HIMSS instrument is mounted on the forward surface of the Eos observatory (Figure 1-1). The payload support structure supporting the sensor attaches to the three longerons of the observatory.

1.2.1 INSTRUMENT CONCEPT

The HIMSS instrument, Figure 1-2, comprises two major elements: the HIMSS sensor itself, and the payload support structure (PSS), which supports and attaches the sensor to the observatory. A portion of the power subsystem and the momentum wheel assembly are

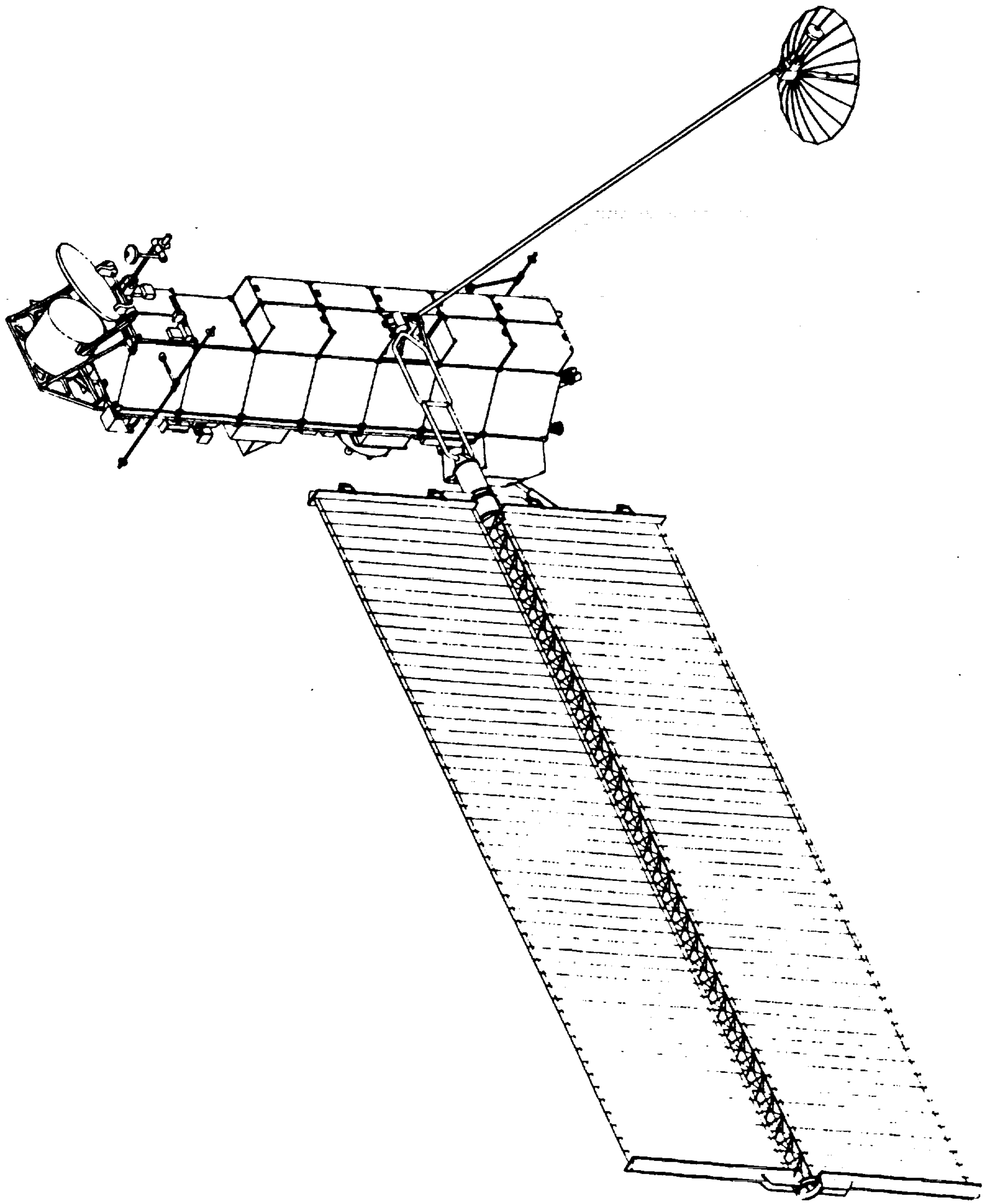

Figure 1-1. The Eos -A observatory showing the HIMSS position at the front end of the platform.

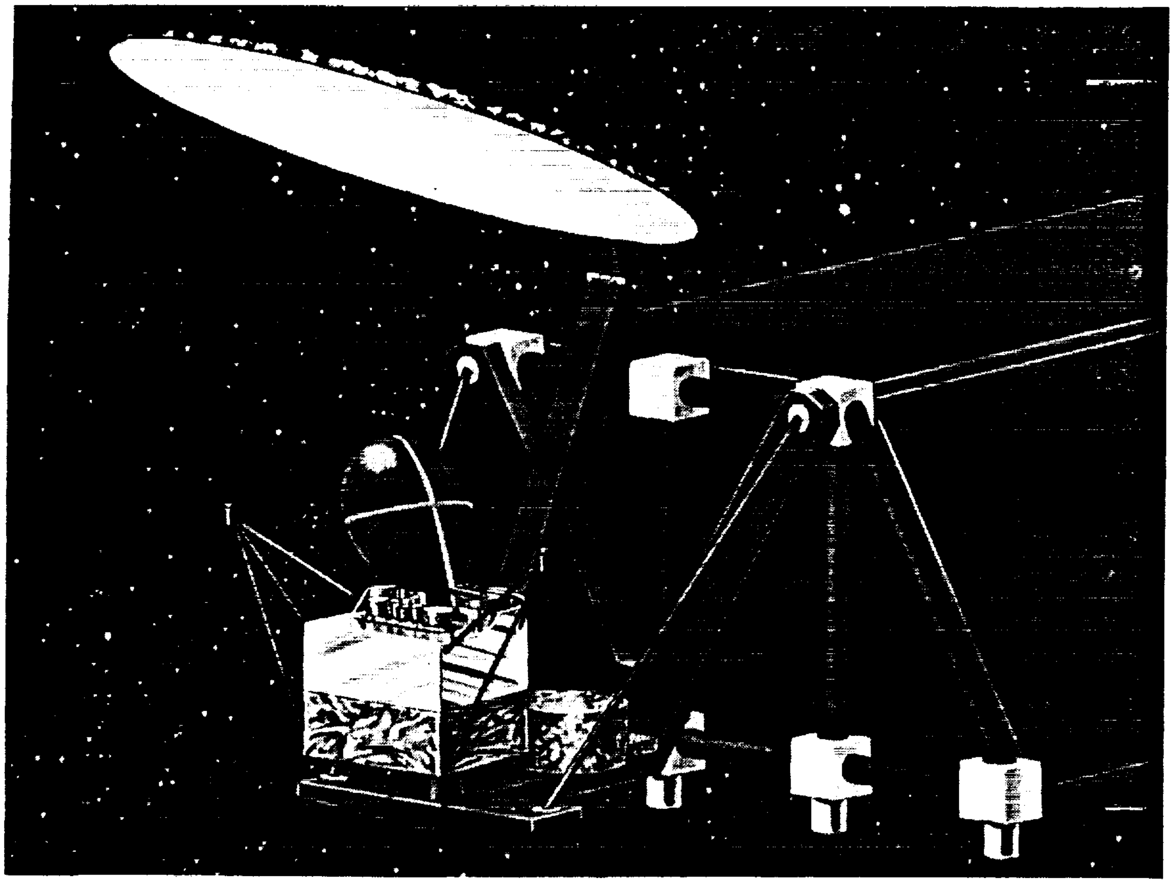

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Figure1-2. The HIMSS instrument concept. The major elements are the 2.2m reflector, the smaller cold sky reflector, the spun assembly with the electronics, the cylindrical momentum wheel, all supported by the payload support structure.

mounted on the PSS along with the sensor. Two units supplied by the payload integrator, the bus data unit (BDU) and the bus select relay (BSR) are also mounted on the PSS.

The HIMSS sensor consists of spun and despun portions. The spun assembly houses the radiometer electronics and the feed assembly. The reflector and its supporting structure are also part of the spun assembly. The spin rate is approximately 40 revolutions per minute (rpm).

The despun assembly mounts to the PSS and supports the calibration (two warm loads and one cold load, also known as the cold sky reflector) loads. These calibration loads are thus fixed in position relative to the observatory, with the feeds in the spun assembly passing beneath them during each revolution. The cold sky reflector has a constant and clear view of deep space in the direction away from the sun. The warm loads' temperature is monitored very accurately; passive thermal control (no heaters) is used to ensure temperature gradients across the loads are minimized.

The sensor, in both , stowed and deployed configurations, and the PSS are designed so as to meet the envelope constraints and also not to protrude beyond the nadir facing plane on which most of the other observatory instruments are mounted. A clear field of view for the other Eos instruments is thus assured.

The deployment scheme of the HIMSS instrument is simpler and therefore more reliable than that of the SSM/I instrument. (SSM/I has a complex two-step deployment scheme) The HIMSS deployment mechanism consists of a simple spring-loaded hinge at the end of the reflector support structure. Prior to deployment, the reflector is supported by this hinge mechanism and two support brackets, to which it is attached with self contained pyrotechnic bolts. When the command for deployment is sent, the pyrotechnic devices are fired, releasing the reflector which then rotates slowly up into the deployed configuration.

1.2.2 HIMSS BLOCK DIAGRAM

The HIMSS instrument consists of 5 major subsystems (see Figure 1-3): the antenna, receiver, signal processing, power, and the structures, mechanisms and controls subsystems. The reflector and feedhorns collect RF energy emitted by the earth which is then conducted to the receiver subsystem via coaxial cables and waveguide. In the receiver, the signals from the 20 baseline (plus 5 optional 50-60 GHz) channels are amplified, downconverted, reamplified, and detected.

The signal processing subsystem multiplexes the channels and performs an analog-to-digital conversion. The resulting science data are multiplexed with instrument telemetry data and then read out to the standard interface connector (SIC). Commands from the observatory bus data unit (BDU) are routed to the signal processing unit for distribution within the HIMSS instrument.

The spun section is supported by the bearing and power transfer assembly (BAPTA). The BAPTA motor speed is controlled by the BAPTA control electronics (BCE). The angular momentum of the spun section is compensated by the momentum wheel assembly (MWA). The combined angular momentum of the spun section and MWA is maintained equal to zero by the interaction between the BCE and the speed control unit (SCU), which regulates the speed of the MWA.

Power for all electronics and motors is provided by a two stage power subsystem. The preconverter provides for an initial conversion of the 120V observatory bus to 52V. This voltage is transferred across the electric contact ring assembly (ECRA) within the BAPTA. The bias power supply in the spun section then converts 52V to the various voltages required by the units in the spun section.

The spun structure is rigidly supported during launch and prior to deployment by a Marman clamp around the base of the BAPTA. The Marman clamp is released by the firing of pyrotechnic devices.

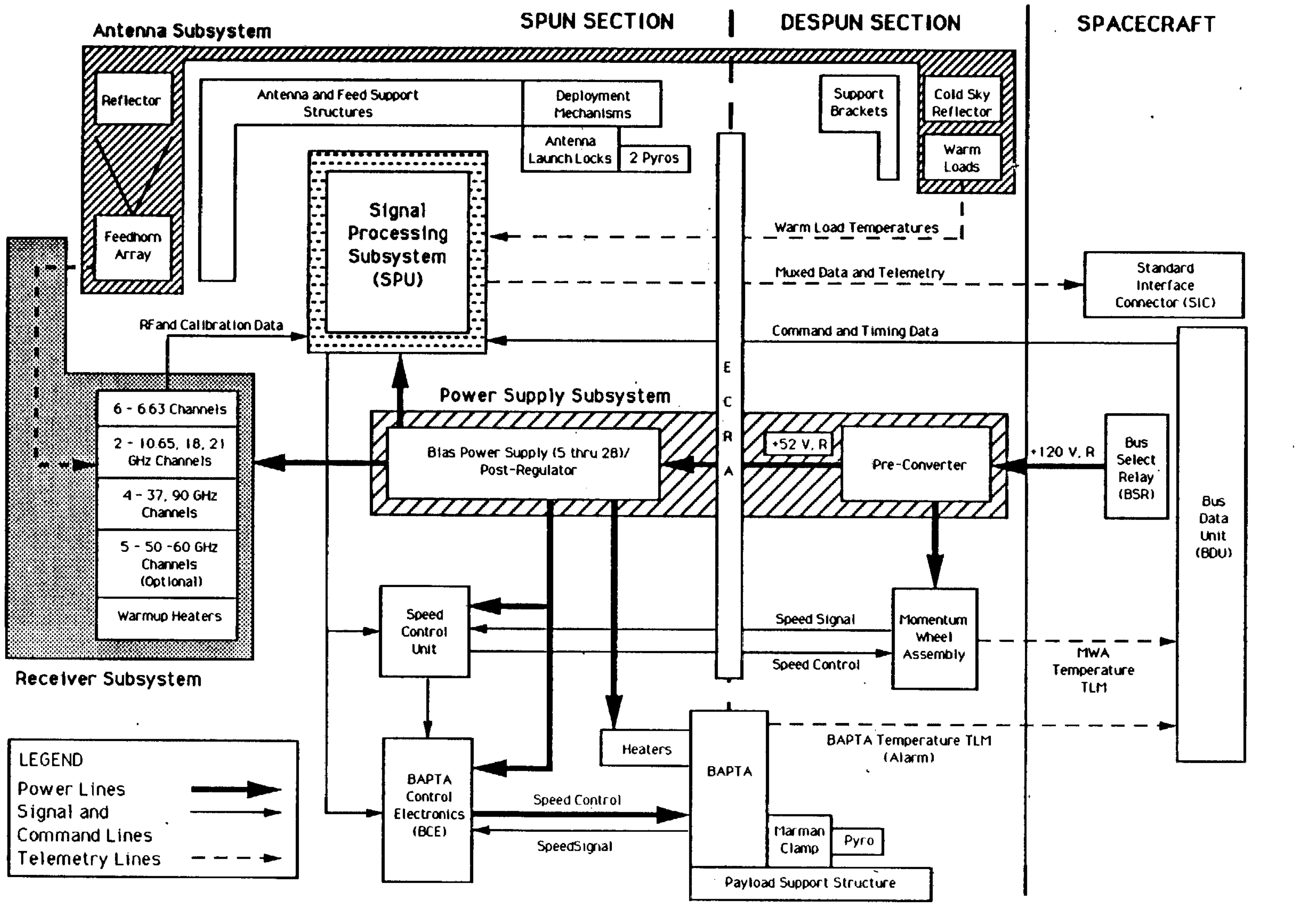


Figure 1-3. HIMSS block diagram shows the major instrument components, as well as the interfaces with the observatory.

1.2.3 RADIOMETRIC PERFORMANCE

The HIMSS instrument satisfies all of the current science requirements. Analysis indicates that the bandwidth of the 90 GHz channels would need to be increased significantly to achieve the required temperature resolution. For the same reason, the bandwidth of the 18 and 21 GHz channels needed to be increased slightly, and pixel averaging was required in the 50-60 GHz channels. Consultations with Marshall Space Flight Center (MSFC) and Remote Sensing Systems have concluded that it is acceptable to increase the channel bandwidth in all these channels to those indicated in the accompanying table, and pixel averaging will be used in the 50-60 GHz channels.

The compliance and performance with the other stated requirements are discussed in section 2.1.1.

1.2.4 HIMSS SCAN GEOMETRY

The HIMSS instrument is designed with 8 feedhorns, including two at 37 GHz and two at 90 GHz, each optimized for its particular center frequency. The feeds are mounted side by side, with the higher frequency feeds clustered near the focal point of the reflector, and the lower frequency feeds located somewhat farther away.

The instantaneous areas over which the feed/reflector pattern is projected is depicted in Figure 1-4. As the sensor scans across the swath, the signal processing unit samples each feed in sequence so that the resulting sampled data represent microwave emissions criginating from coregistered footprints on earth. The 90 GHz footprint is only 5 km in the cross scan direction. The two 90 GHz feedhorns assure contiguous coverage. At 37 GHz the footprint is sufficiently large to provide full coverage; the two 37 GHz feedhorns provide Nyquist sampling of the data, which was a scientific requirement.

1.2.5 INSTRUMENT HERITAGE

The heritage from the SSM/I instrument is a major factor in reducing the overall program risk associated with the HIMSS Program. The overall HIMSS instrument architecture is based on that of the SSM/I instrument, and most of the detailed subsystem and unit designs are derived from SSM/I designs. Analytical programs used and proven during SSM/I development will be employed for the HIMSS design.

The receiver and signal processing subsystems are very similar to those of SSM/I. The receiver subsystem is virtually identical except for the addition of the 6.63 and 10.65 GHz channels and the incorporation of low noise amplifiers (LNAs) at the front end of the receivers. The signal processing unit is essentially an expanded SSM/I unit, with the processing capability extended from 7 to 20 (baseline) or 25 (baseline plus optional) channels.

The power subsystem will use the post regulators from SSM/I, expanded for a larger number of circuits. The 52V bias power supply is modified from a unit developed for the UHF Follow-on program. The modifications are required simply to provide the specific voltage outputs required by the HIMSS instrument. The preconverter, which converts the 120V observatory bus to 52V, is a completely new unit.

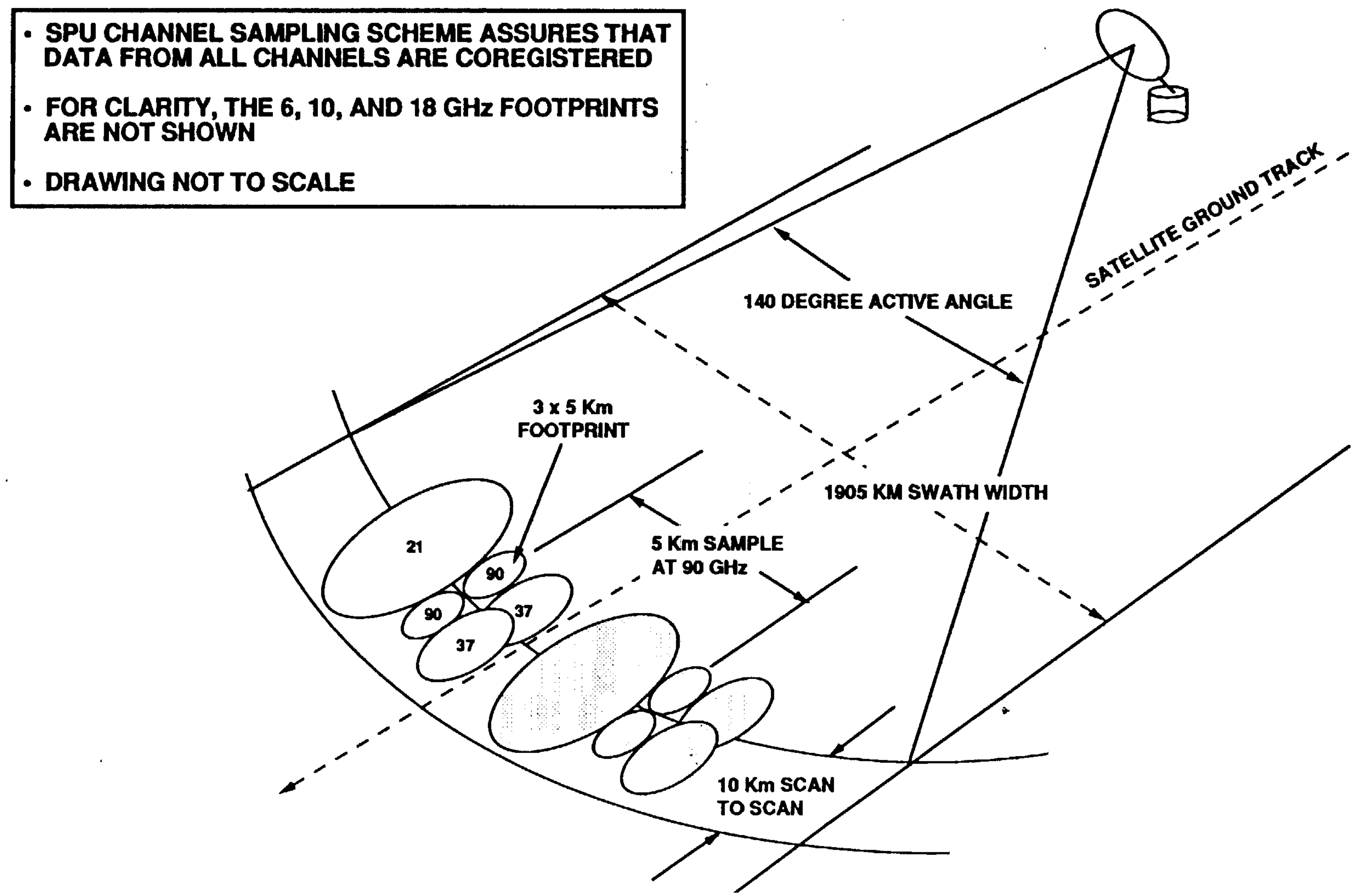


Figure 1-4. HIMSS scan geometry and sample footprints; the signal processing unit will assure the coregistration of the different channels footprints.

Most of the mechanisms and controls units are also adapted from SSM/I units. The BAPTA, probably the most critical unit in any spinning radiometer, is unchanged from SSM/I. The BAPTA control electronics have been modified slightly to accommodate the higher spin rate of the HIMSS instrument.

A larger momentum wheel is required for the HIMSS instrument than was used for the smaller SSM/I instrument. We will use the same momentum wheel developed and qualified for the UHF Follow-on Program spacecraft. A new speed control unit will be built to interface between the momentum wheel and the BAPTA control electronics.

Because the HIMSS instrument is so much larger than the SSM/I instrument, the HIMSS structure will be a new design. The PSS will also be a new design, since SSM/I mounted directly to the DMSP spacecraft without the need for a separate support structure.

1.3 TRADE STUDIES

The trades analyses weighed the compliance with specifications issue versus cost and reliability. Table 1-1 lists the major trades and the rationale behind the choice made. More details on these trades are found in the subsystems description sections.

Table 1-1. The major trade studies during the HIMSS study concentrated on meeting the requirements at the lowest risk and cost possible. The chosen architecture is shown in bold.

TRADE	RATIONALE
Receiver subsystem: **Heterodyne** vs. direct detection	Heritage, flight experience, lower cost
Signal processing subsystem: Logic **VLSI** vs. microprocessor	No flight s/w needed, lower cost
Power subsystem: Slip ring transfer voltage **52 V** vs. 120 or 28V	Least impact to the BAPTA, existing design for the 52 to 28V supply

2.0 HIMSS INSTRUMENT DESCRIPTION

2.1 PERFORMANCE CHARACTERISTICS

The Hughes conceptual design of the HIMSS instrument complies with practically all SOW specifications. Any exceptions are discussed. The design also complies with the General Instrument Interface Specifications (GIIS).

2.1.1 HIMSS PERFORMANCE

Table 2-1 lists all SOW-Appendix A specifications and the respective HIMSS estimated performance.

Certain parameters were not specified in the SOW. The power consumption during steady state operations is 124 Watts, with a peak of 270 Watts for approximately 20 minutes at sensor spin-up.

Two important parameters for a spinning sensor are the static and dynamic imbalance. Hughes is proposing an active balancing mechanism which will reduce the imbalance in orbit to negligible values (see Section 2.3.2). Table 2-2 lists these parameters.

2.1.2 HIMSS POWER PROFILE

The power profile for the HIMSS instrument from sensor deployment through spin-down, if necessary, is shown in Figure 2-1. The sequence of instrument commands is shown, along with the resulting instrument status. The first command is for antenna pyrotechnic firing. This command releases the two tie down points of the main reflector, and the reflector deploys to the operational configuration. The deployment mechanism consists of a simple spring driven hinge with a latch. The second command fires the Marman clamp pyrotechnics. The Marman clamp is a device that ties the spun and despun portions of the BAPTA together, thus removing the dynamic loads encountered during launch. The next two commands, power enable and momentum wheel assembly (MWA) enable, apply power to the electronics.

Since the BAPTA must be operated in a narrow temperature range, it is recommended that its temperature be in the upper half of its operational temperature range of 4 to 38 degrees C. To achieve this temperature, the next operation in the turn-on process is to command the warm-up and maintenance heaters on and allow the BAPTA to come up to this temperature range.

Commanding the motor driver and reference clock ON starts the spin up of the sensor and the momentum wheel. At the completion of spin-up, when the instrument is spinning at approximately 40 rpm, the warm-up heater is turned OFF and the receivers are turned ON for normal operation to begin. Spin-up can take 10 to 30 minutes, depending on the maximum allowable peak power. The 270 Watts shown here is the maximum peak power needed for a fast spin-up. This value is lower if the spin-up is allowed to be longer.

Table 2-1. Specifications and estimated performance. Hughes design complies with all specifications.

PARAMETER	SPECIFICATION FROM SOW - APPENDIX A	ESTIMATED PERFORMANCE	COMMENTS
Number of Channels	14	Comply	Additional 6 channels (due to addition of a new horn and different accounting)
Receiver Type	Direct Amplification, or if heterodyne, a small rejection band will be included at the local oscillator to reduce noise.	Heterodyne with small rejection band	See results of trade study in Section 2.2.5.3
Sampling Rate Along and Across Track, Km	6.6, 10.7, 18.0, 21.0, 37, 50-60 GHz: 10, 90.0 GHz: 5	Comply	
Effective Aperture Width, m	>2.0	Comply	
Nadir Angle, Degree	46	Comply	
Active Scan Angle Degree	140	Comply	
Beam Center Co-registration	Goal: <3Km among all frequencies except 90 GHz (and 37 GHz)* otherwise: <3 Km between 6.6 and 10.7 GHz and <3Km between 18, 21 and 37 GHz	Comply (2.5 Km among all except 90 and 37 GHz)	Contiguous coverage at 90 and Nyquist sampling at 37 GHz
Lifetime, years	5	Comply	
Reliability	0.7	Comply	Goal of 0.85 over 5 years (see Section 2.4)
Maximum residual angular momentum, N-m-sec	0.1	Comply	GIIS (1/15/90) requires 0.5 N-m-sec
Maximum Mass, Kg Instrument w/o PSS Instrument with PSS	 130 222	 Comply Comply	Total mass 210 KG with 30% contingency

* New requirement for dual feeds at 37 GHz per 13 September, 1989 letter from Roy Spencer

Table 2-1 (continued). Specifications and estimated performance. Hughes design complies with all specifications.

PARAMETER	SPECIFICATION FROM SOW - APPENDIX A	ESTIMATED PERFORMANCE	COMMENTS
Pointing error, degree	0.2 across scan 0.3 along scan	Comply	
Temperature accuracy, °C	1.5	Comply	
Calibration strategy	• Every scan, cold sky and warm load through Earth-Observation Feedhorn • Integration time >4 times the longest integration time of the earth observations	Comply	SSM/I calibration strategy
Calibration Errors	• Cold calibration-induced errors due to the earth's and sun's influence on cold view ≤0.1° of brightness temperature	Comply	Error budgets based on SSMI experience (<0.1°)
	• Hot calibration-induced errors due to warm load reflections ≤0.1° of brightness temperature	Comply	
Feedhorn Spillover Pattern	• The portion of the feedhorn pattern that is not subtended by the main reflector shall not exceed 2% of the total normalize feedhorn gain		
Beam Efficiencies	a) Mainbeam (2.5 x 3dB beamwidth) efficiency ≥91% at all channels	Comply	
	b) Main beam plus near-sidelobe (total of 7.5 x 3 dB beamwidth) ≥96%	Comply	
	c) Far sidelobe power (remaining power from earth excluding main beam and near-sidelobes) <0.2% (0.1% goal at 6.6 and 10.7 GHz)	Comply (with proposed new specs)	Details in the antenna subsystem discussion, Sec. 2.2.4
	d) Spillover power (feedhorn spillover and far sidelobe power from cold space) <4%	Comply	Details in the antenna subsystem discussion, Sec. 2.2.4
Cross Polarization	$\frac{\text{Total Cross-Pol Power}}{\text{Total Co-Pol Power}} < 1\%$	Comply	

Table 2-1 (continued). Specifications and estimated performance. Hughes design complies with all specifications.

PARAMETER	SPECIFICATION FROM SOW - APPENDIX A					ESTIMATED PERFORMANCE	COMMENTS
Channel Characteristics	Channel Number	Frequency (GHz) and Pol'n	Bandwidth MHz	RESOLUTION Temperature K	RESOLUTION Spatial Km**		Achievable Bandwidth MHz
	1 & 3	90, V	1500	0.7	5	Comply except for bandwidth	6000
	2 & 4	90, H	1500	0.7	5		6000
	5 & 7@	37, V	1000	0.4	10		950
	6 & 8@	37, H	1000	0.4	10		950
	9	21, V	500	0.4	17		620
	10	21, H	500	0.4	17		620
	11	18, V	500	0.4	17		570
	12	18, H	500	0.4	17		570
	13	10.65, V	400	0.3*	31		400
	14	10.65, H	400	0.3*	31		400
	15.17.19	6.63, V	170	0.3*	50		170
	16.18.20	6.63, H	170	0.3*	50		170
	21	50.3	200	0.5	10		
	22	53.595 V ±0.115	340	0.5	10	Comply; Use Pixel Averaging	
	23	54.35 H	400	0.5	10		
	24	54.9 H	400	0.5	10		
	25	57.95 H	400	0.5	10		

* 150 Degree Scene Temperature
** Refers to the 3dB beamwidth Major Axis
@ Additional Specification per 13 September, 1989 letter from Roy Spencer

Table 2-2. Additional Specifications. The imbalance specifications need to be reviewed (TBR)

PARAMETER	ADDITIONAL SPECIFICATIONS	ESTIMATED PERFORMANCE	COMMENTS
Power, W			
• Steady State	85	124	85 W per AO Proposal
• Peak		270	270 W peak occurs during spin-up only
Imbalance			
• Static, Kg-m	≤0.0044 (TBR)	0.0053	Active balancing mechanism can provide:
• Dynamic, Kg-m^2	≤0.0059 (TBR)	0.0059	0.0005 Kg-m (static) 0.0005 Kg-m^2 (dynamic)

2.1.3 GENERAL INSTRUMENT INTERFACE SPECIFICATION (GIIS) COMPATIBILITY

The Hughes HIMSS design, in general, complies with the GIIS. Tables 2-3, -4, and -5 show our compliance and estimated performance for the mechanical (sec 3), thermal (sec 4), and electrical/data (sec 5) interfaces. Preliminary review of the specifications in section 6, component fabrication, and section 11, GSE interfaces, indicates that Hughes can comply with all these specifications.

Table 2-6 shows the pertinent excerpts on the compliance with the magnetic field, EMI and contamination control specifications.

2.2 INSTRUMENT CONCEPTUAL DESIGN

2.2.1 OVERVIEW

Details of the conceptual design subsystems and their elements follows. The requirement flowdown to the subsystem are reiterated, and the trades considered are discussed. Each element and its function is then described.

2.2.2 STRUCTURES

The HIMSS structures design will benefit from the SSM/I design, specially in the spinning section housing the electronics. The reflector support has a new design in order to accommodate the larger reflector and the simpler deployment scheme.

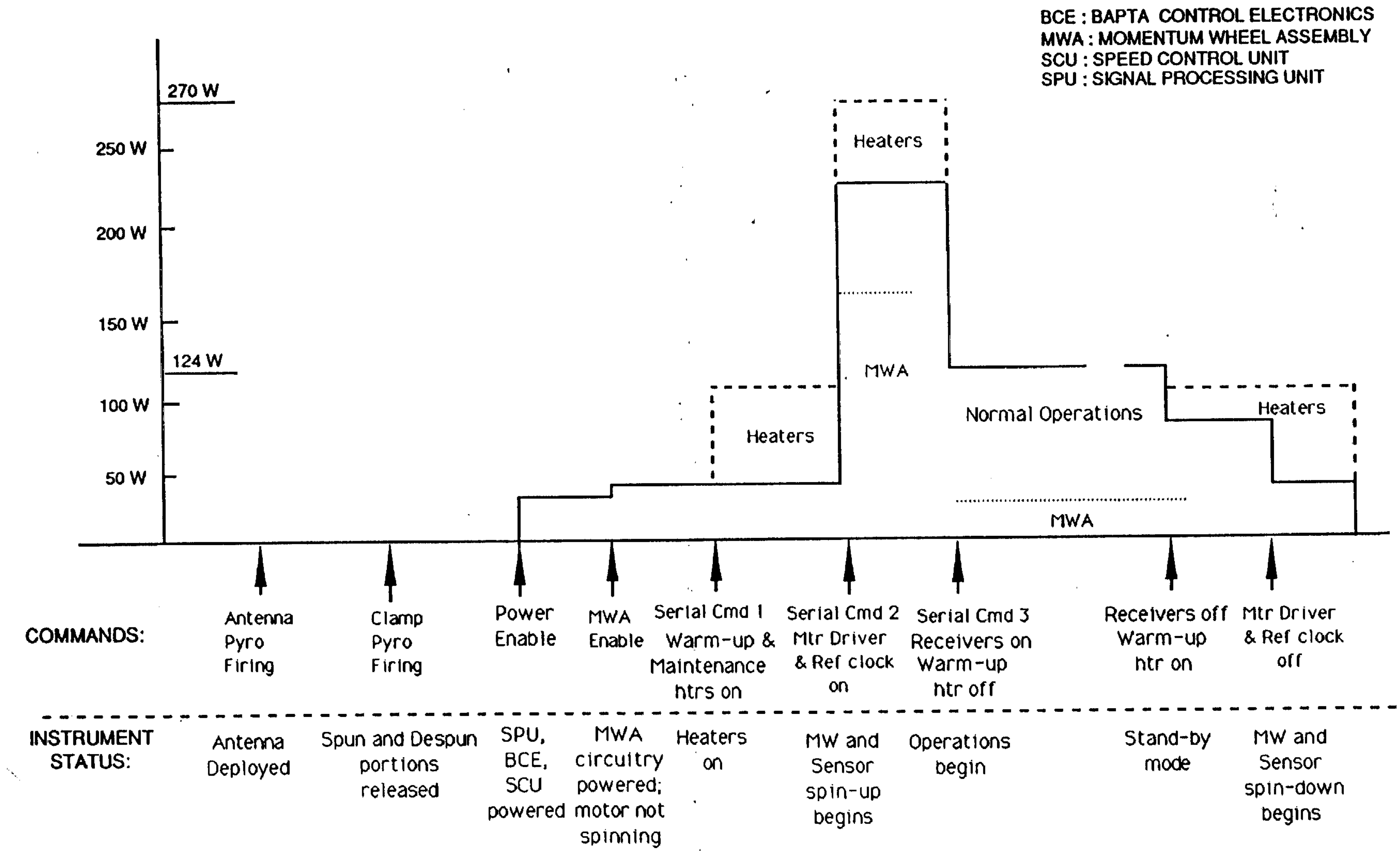


Figure 2-1. HIMSS power profile from deployment through operational, and spin down, if necessary. The steady state power consumption is 124 W.

Table 2-3. General Instrument Interface Specification (GIIS) - Mechanical interfaces

GIIS SECTION		SPECIFICATION FROM GIIS	ESTIMATED PERFORMANCE	COMMENTS
3.1.1	Mass	N/A	222 Kg	Not mounted on a PMP
3.1.2	Size/Envelope	N/A	Comply with shroud and deployed envelopes**	
3.1.3	Center of Mass Accuracy	0.1 in.	Comply	
3.1.4	Moments and Product of Inertial Accuracy	5%	Comply	
3.1.5	Uncompensated Momentum	0.5 N-M-sec	Comply	Achieve 0.06 N-m-sec
3.1.6	Mechanical Disturbance,Torque: Static Dynamic	 0.0044 Kg-m* 0.0059 Kg-m^2 *	 Comply Comply	Active balancing achieve 0.0005 Kg-m and 0.0005 Kg-m^2
3.1.7	Mechanical Interface Drawings	Listing	Comply	
3.1.8	Fields-of-View		+160°/-70° from velocity vector	
3.2	Instrument Mounting	N/A		Not mounted on a PMP
3.3.1	Reference Coordinate System	Figure 3-8	Comply	Observatory along-track = sensor cross-scan
3.3.4	Alignment Cube/Mirrors	Provide 1 cube or 2 mirrors	Comply	Optical cube on the PSS
3.7	Dynamic Characteristics	Provide FEM — Frequencies below 100 Hz		
3.8 to 3.11			Comply	
3.12.1	Mounting Hole Template	Provide template to payload integrator		Payload integrator to provide template to instrument provider

* Per letter from P. Pecori dated May 8, 1989.
** Per GE memo dated September 12, 1989.

Table 2-4. General Instrument Interface Specification (GIIS) - Thermal interfaces

GIIS SECTION		SPECIFICATION FROM GIIS	ESTIMATED PERFORMANCE	COMMENTS
4.1.2	Instrument Thermal Design and Control	Local, central or hybrid	Local	
4.1.3	Heat Transfer	< 0.01 w/sq. in.	0.03 w/sq. in.	Preliminary analysis result
4.1.4	Temperature Maintenance	Survival heaters	Comply	
4.4	Instrument Interface Design	Figure 4.1	N/A	
4.4.4	Thermal Isolation	0.01 w/sq. in.	Comply	
4.6	Instrument Thermal Control Hardware	Supplied by instrument provider	Comply	

Table 2-5. General Instrument Interface Specification (GIIS) - Electrical interfaces

GIIS SECTION		SPECIFICATION FROM GIIS	ESTIMATED PERFORMANCE	COMMENTS
5.1 to 5.4			Comply	
5.5.1.2.1	Discrete Safe Mode Signals	Upon receipt of safe mode signal, enter a safe condition	Comply	Safe mode signal will remove power from the instrument; short imbalance period
5.5.1.3.4	Serial Command Interface	Figure 5-14	Comply	Interface not bi-directional
5.5.2	Time and Frequency References			Not used by HIMSS
5.6.1.1	Digital Discrete Telemetry	Verification of ON/OFF status of instrument power relay	Comply	
5.6.1.2	Passive Analog Telemetry	Temperature data from inside the sensor	Comply	BAPTA temperature
5.6.1.3	Serial Digital Telemetry			Not used by HIMSS
5.6.2	Engineering Telemetry			In the science sata stream
5.7	Ancillary Data			Not used by HIMSS
5.8	Scientific Payload Data		Comply	

Table 2-6. General Instrument Interface Specification (GIIS) - Magnetic fields, EMI and contamination control environments.

GIIS SECTION	SPECIFICATION FROM GIIS	ESTIMATED PERFORMANCE	COMMENTS
7.1 Platform Generated Magnetic Fields	No permanent damage if exposed to 10.0 gauss	Comply	
7.2 Instrument Generated Magnetic Fields	< 0.1 amp-m^2	Comply	Instrument will be compensated.
8.2 Interference Requirements, Launch Phase			
8.2.1 EMC Requirements	Listing	N/A	HIMSS will be OFF during launch.
8.3 Interference Requirements, Orbital Operations			HIMSS design based on same criteria used for SSM/I; SSM/I successfully passed all MIL-STD-1541 tests.
8.4 Susceptibility Requirements, Orbital Operations			
9.1 Instrument Cleanliness	Provide contamination control requirements and sources	Comply	No requirements. Entire sensor in TV, BAPTA designed to minimize lubricant vapor escape.
9.2 Instrument Venting	Specify vents	N/A	HIMSS not hermetically sealed.
9.3 Covers and Purges	Provide covers and purge requirements	Comply	Covers on the horns and VDA surfaces. Purge on slip rings in some Earth environments.
9.4 Materials Outgassing	Outgassing done by instrument provider	Comply	

2.2.2.1 Elements

The structural elements are divided into two sections, the spinning and the despun sections. The spinning section includes the reflector support and the electronics housing (sensor structure). The despun structure includes the payload support structure (PSS) and the calibration loads support. These elements are further discussed in paragraph 2.2.2.5.

2.2.2.2 Requirements

The requirements for the structures design are identified in Table 2-7. Imbalance is considered the most significant requirement. This requirement dictates that considerable care be used in the placement of all electronics subassemblies in the spinning portion of the instrument. Additionally, the alignment between the reflector and the feedhorn array, as well as the deployment repeatability dominates the structural stiffness requirements (the numbers are presented later in this report).

2.2.2.3 Design Trades

One of the challenges that the HIMSS requirements posed was the problem of how to configure the instrument such that it would fit within the envelopes that had been defined for launch and on-orbit. Difficulties arose when the problem of deployment was considered. Some potential solutions that were considered were to use four bar linkage for the reflector support or to use the same approach that was used on SSM/I. These solutions were discarded on the grounds that they either did not provide a stiff enough structure, or did not meet the stringent balance requirements of HIMSS. The solution that was adopted reduces all of the aforementioned problems.

2.2.2.4 Heritage

The larger reflector being considered for the HIMSS instrument dictates that the structures used to support it must be new designs. Hughes, however, has successfully developed space structures that are larger and have had to operate under more demanding requirements than have been specified for the HIMSS program.

2.2.2.5 Design

The main elements of the HIMSS structure design are: a) the payload support structure (PSS), and b) the sensor structure. The deployment sequence required special attention due to the spatial constraints during launch and on-orbit and is discussed in the following paragraphs.

2.2.2.5.1 Payload Support Structure (PSS)

The purpose of the payload support structure (Figure 2-2) is to provide a platform for mounting the spinning portion of the instrument. The structure must be stiff enough to support the instrument during both the launch phase and the on-orbit phase of the mission.

Table 2-7. Structures, Mechanisms and Controls requirements. The most challenging requirement is the imbalance, and that is being met with an active system on orbit.

EFFECTIVE APERTURE WIDTH	$\geq$ 2 METERS
NADIR ANGLE	46 $\pm$ .05 DEGREES
ACTIVE SCAN ANGLE	140 DEGREES
POINTING ERROR	$\leq$ 0.2 DEGREES ACROSS SCAN $\leq$ 0.3 DEGREES ALONG SCAN
MASS	222 KGS (TBR)
- EXCLUDING PAYLOD SUPPORT STRUCTURE	130 KGS
IMBALANCE	
- STATIC	$\leq$ 0.0044 Kg m (TBR)
- DYNAMIC	$\leq$ 0.0059 Kg m^2 (TBR)
RESIDUAL ANGULAR MOMENTUM	$\leq$ 0.1 NEWTON- METER-SECOND
LIFETIME	> 5 YEARS
RELIABILITY	> 0.7
ENVELOPES	
- DEPLOYED	SEE FIGURES
- STOWED	SEE FIGURES

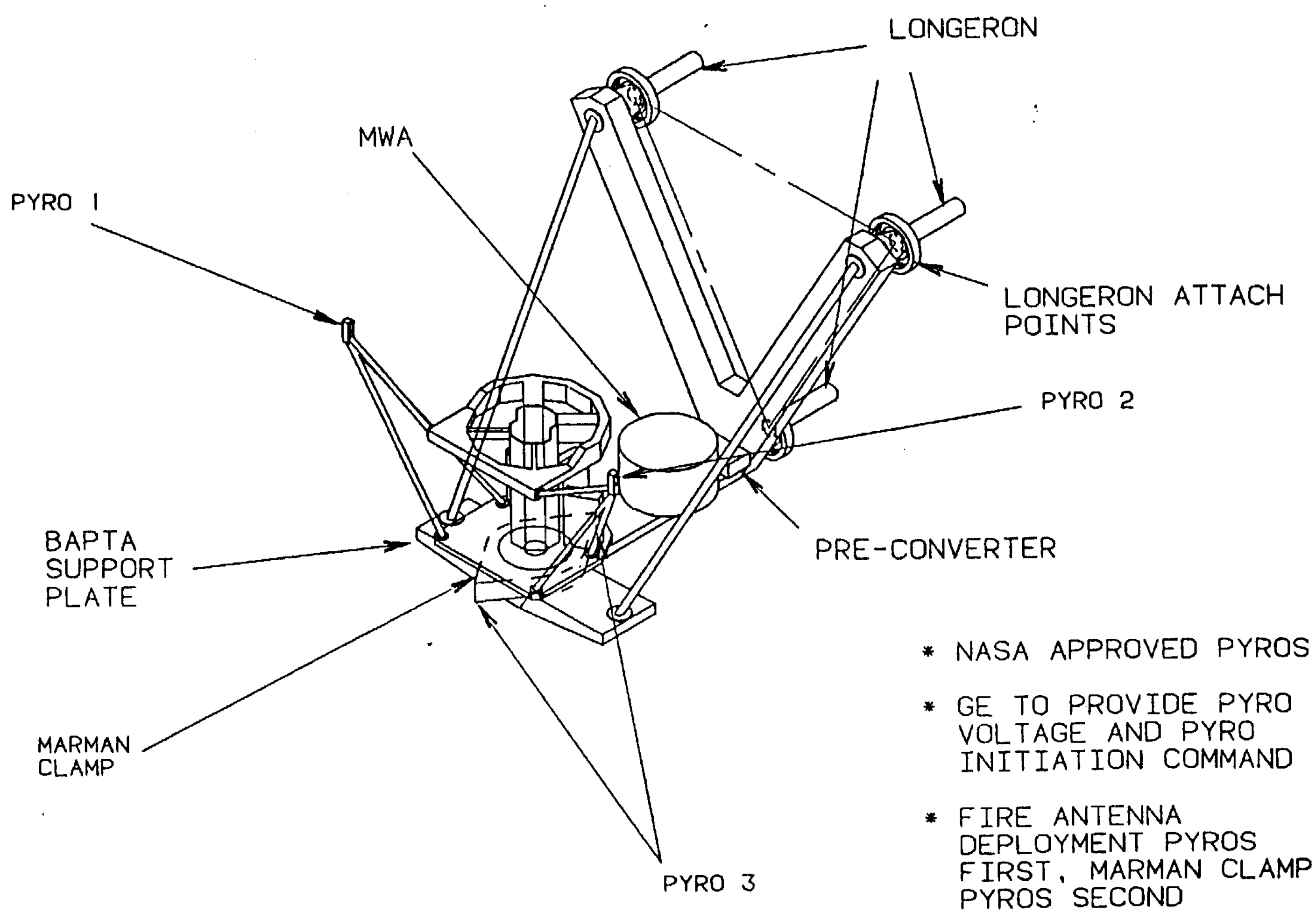


Figure 2-2. The payload support structure (PSS) is shown with the electronics enclosure, MWA and the preconverter. The two payload integrator units are not shown. The three sets of pyrotechnics are pointed out.

During the on-orbit phase of the mission the support structure will be required to provide a high level of torsional stiffness to assure that the instrument maintains the desired spin orientation. To fill the high torsion requirement, the support structure is to be constructed principally using box beams. For alleviation of the launch loads two tubular struts connect the outer reaches of the platform to the two available longerons in order to prevent large bending moments. The payload support structure will also provide a mounting location for the momentum wheel assembly, the power subsystem's preconverter, and the two units supplied by the payload integrator: the bus select relay (BSR), and the bus data unit (BDU).

2.2.2.5.2 Sensor Structure

The sensor structure requirements are: a) maintain the proper alignment between the reflector and the feedhorn array, b) provide a thermal path for the electronics that it houses, and c) be easily serviceable. The proper alignment requirement between the reflector and the feedhorn array dictates that the top part of the sensor structure be a rigid construction and, as such, the reflector support boom will be a box beam construction. The sensor structure must support all of the electronic units that are required to be in the spinning portion of the instrument. Provisions must be made for a thermal path that would meet the requirements of conducting the heat away from each electronic unit. The serviceability of the sensor is an important factor during integration and test and maintaining schedule. The proposed open architecture will meet this requirement. The conceptual design shown in Figure 2-3 addresses all of these considerations.

2.2.2.5.3 Deployment Sequence

The HIMSS instrument will be required to meet two different configurations, one for the launch and ascent phase of the mission and one for the on-orbit operation. The main difficulty that must be overcome during ascent phase is fitting the reflector inside the launch shroud. The problem can be solved by providing a single pivot point at the top of the deployment boom and orienting the instrument as shown in the stowed configuration in Figure 2-4. Once the instrument has arrived on station the reflector will be deployed via a single deployment actuator. The approach shown meets all the requirements with minimum complexity. The envelope of the launch shroud is shown in Figure 2-4 by the broken lines. The tapering of the shroud is represented by the multiple lines. By orienting the instrument as shown and folding the reflector down, the instrument fits well within the allowable envelope. The highest part of the instrument, the support boom, will lie along a radial line originating at the center of the spacecraft and will maintain ample clearance from the shroud. Also shown in the figure are the launch supports and separation bolts for the reflector. When the pyrotechnics in the separation bolts are fired, the reflector will be deployed by the spring driven deployment actuator located at the top of the reflector support structure.

The deployed configuration is also shown in Figure 2-4. The deployed sensor fits within the envelope defined in the G.E. memo dated September 12, 1989.

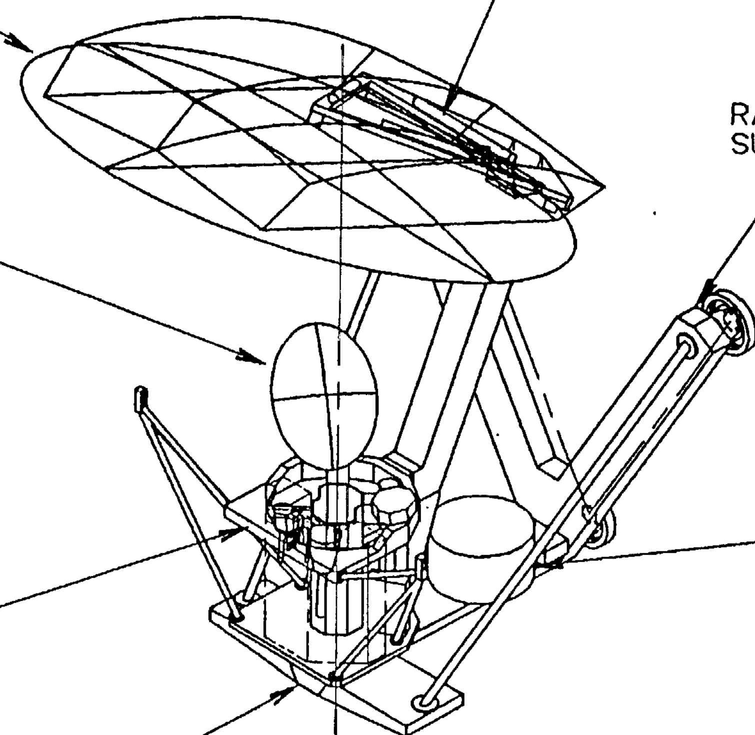


Figure 2-3. The HIMSS instrument concept shows the 2.2m reflector with the active balancing mechanism, the cold sky reflector (for calibration), the spun/despun assembly (the electronics housing) and the PSS with the attachments to the observatory.

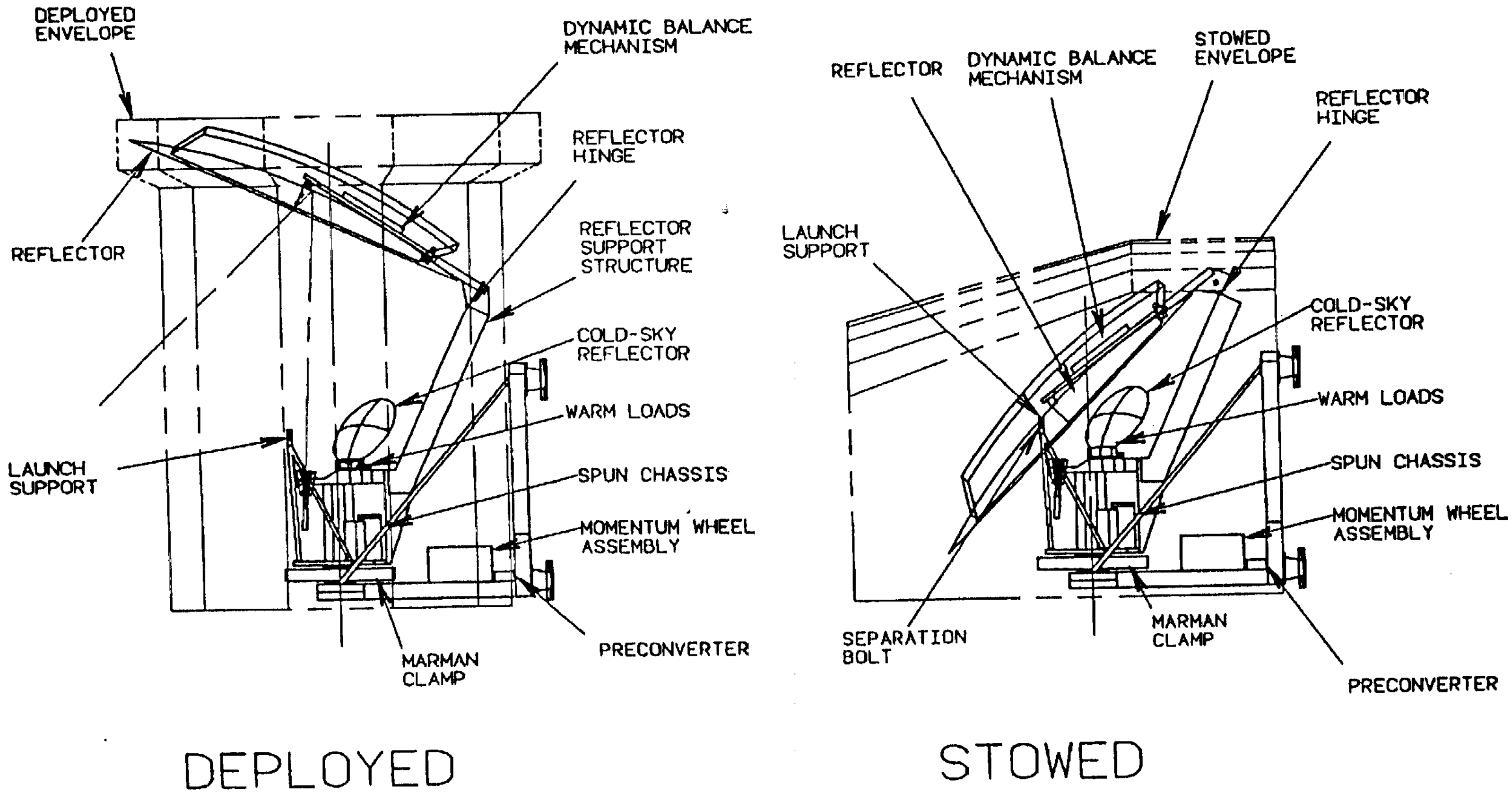


Figure 2-4. The deployed and stowed configurations illustrating how the Hughes concept meets the envelope constraints

There are three sets of pyrotechnics on the HIMSS instrument (see Figure 2-2). They have two objectives. The pyros labelled #1 and #2 are used to release the reflector from the stowed position during the reflector deployment. The pyros labelled #3 are used to release the Marman clamp prior to instrument spinup. The Marman clamp joins the spun and despun parts of the BAPTA together in order to remove the shear stresses occuring during launch.

Once the satellite is on orbit, the order of deployment will be as follows:
1) Pyros #1 and #2 will be detonated, releasing the reflector for deployment
2) Pyro #3 will then be detonated, releasing the Marman clamp at the base of the BAPTA.

After this phase, the HIMSS instrument is spun-up and is then ready for operations.

2.2.3 MECHANISMS AND CONTROLS SUBSYSTEM

The philosophy that has been adhered to during the development of the HIMSS architecture has been to use previously developed and flight proven equipment wherever possible. Accordingly, the HIMSS effort has drawn extensively from the experience and the existing equipment already developed for the SSM/I program and other Hughes programs.

2.2.3.1 Elements

The major elements included in the Mechanisms and Controls Subsystem are:

a) Bearing and Power Transfer Assembly (BAPTA)
b) Momentum Wheel Assembly (MWA)
c) BAPTA Control Electronics (BCE)
d) Speed Control Unit (SCU)
e) Reflector Deployment Actuator (RDA)
f) Active Balancing Mechanisms (ABM)
g) Marman clamp
h) Pyrotechnics

2.2.3.2 Requirements

The top level requirements have already been presented in Table 2-7, page 20. The first four listings refer to the instrument's field of view and do not present any difficulties. The mass of the instrument, likewise, does not appear to be overly restrictive; however, the imbalance numbers will require considerable attention. In particular, the dynamic balance number will necessitate the addition of an active balance mechanism. The residual angular momentum is easily managed through control of the momentum wheel assembly. The lifetime and reliability specifications do not present any difficulties. The preliminary design effort has shown that the instrument meets the envelope constraints in both the stowed and deployed configurations.

2.2.3.3 Design Trades

In evaluating the program requirements, many design trades have been made. The criterion that has most influenced the design decisions has been the requirement to minimize cost and risk by using already existing designs as much as possible. Through careful design of the instrument architecture, the majority of the required elements can be selected from an inventory of existing and readily available equipment. The one notable exception has been the Speed Control Unit. The need for an all new SCU arises from the fact that on other Hughes programs the MWAs are controlled from a central control unit whose application to the HIMSS program would be completely inappropriate. The need for an SCU on the HIMSS program is dictated by the severe momentum control requirements.

An trade analysis was performed on the antenna support structure and deployment mechanism. A four-bar linkage was compared to a fixed box beam design. The fixed box beam approach had more advantages for meeting the HIMSS mission requirements. The chosen approach has better pointing accuracy, better deployment repeatibility, meets the deployment angle requirements (of not being deployed through any other instrument's field of view), and it better fits the launch envelope. The undamped deployment mechanism chosen has a simple design and minimum outgassing. The alternate mechanism, a viscous damper requires heaters.

2.2.3.4 Heritage

The controls for the servo loop as well as the bearing and power transfer assembly (BAPTA) were all developed on the SSM/I program and the only changes that will be required will be an increase in the unit spin rate (40 RPM) and changes to the loop compensator networks imbedded in the BAPTA control electronics (BCE). However, since the BCE is an analog unit, the changes are minor.

The relatively high bus voltage that the observatory is supplying does present a potential problem as regards the electrical contact ring assembly (ECRA). The ECRA unit proposed was developed for the SSM/I program and it was designed for a lower voltage. The HIMSS instrument reduces the 120 volt observatory bus to 52 volts before it is passed across the ECRA. There will be minor modifications to the SSM/I ECRA to assure no electrical breakdown between the slip rings.

The HIMSS program has balance requirements that are considerably more stringent than the SSM/I program. In order to meet the requirements, an active balance scheme has been added to the instrument. The actual mechanisms for balancing are the same units presently being used on the Hughes HS 350 satellite.

The HIMSS instrument has a larger angular momentum than the SSM/I sensor requiring the use of a larger momentum wheel for spin compensation. A momentum wheel assembly (MWA), developed for the Hughes UHF program, will be used.

The spring loaded reflector deployment actuator (RDA) is the same unit that is presently used on the Hughes AUSSAT program.

2.2.3.5 Design

The BAPTA provides the rotating mechanical and electrical interface between the spinning and despun sections of the sensor. Structural elements include a titanium housing and shaft, a steel preload spring, and two stainless steel angular contact bearings. Electrical power and signal transfer is provided by slip rings using silver brush/ring contacts. Two indexing pulse generators and a brushless dc torque motor complete the components of this assembly.

The BAPTA control electronics (BCE) must provide accurate position control of the scanner to ensure accurate location of the data. The BCE phase locks the BAPTA to a clock provided by the signal processing unit. There are three control loops in the BCE: a) initialization (to ensure the correct startup), b) rate (to maintain momentum balance during spinup), and c) position (to maintain position reference and momentum balance during steady state)

The speed control unit (SCU), will be required in order to interface with the MWA to assure that the spin rate of the MWA is such that the angular momentum of the spinning instrument is nulled out. The SCU will consist of a basic speed control loop and can be implemented in either an analog or digital manner. The level of complexity of the compensator should be minimal (second order) and is presently being viewed as a low risk item. At the present time the driver and interfaces required for the active balancing mechanisms are slated to be packaged in the SCU. These items have already been developed on other Hughes programs and will only require a re-packaging effort.

The reflector deployment actuator (RDA) is a simple spring loaded mechanism with no damping. The springs provide a slow deployment, with a stop at the desired on-orbit position.

2.2.4 ANTENNA SUBSYSTEM

The antenna subsystem receives microwave energy from earth. At an instant in time only the energy from a particular footprint is desired. The antenna pattern is required to minimize the collection of microwave energy from the earth outside of the footprint and from any other source such as the spacecraft and other payloads. As the spacecraft is moving relative to the earth, the footprint is also swept transverse to the velocity direction by rotating the antenna at 40 rpm about the nadir axis allowing the beam to collect energy over a ±70° arc of the earth's surface. The calibration of the system is dependent upon the antenna to alternately collect energy solely from a cold and warm source of known and controlled temperatures. The sections which follow will discuss the requirements, design trades and considerations, hardware implementation and related Hughes experience.

2.2.4.1 Elements

The antenna system is comprised of four major groups which all work in concert with each other. A large reflector is designed to capture the microwave energy radiated from the earth and direct it to a multi-frequency feed system. The feed system accepts microwave energy in the two orthogonal (vertical and horizontal) linear polarizations in each of 6 widely spaced frequency bands (an additional high frequency band is optional). For calibration of the system a cold sky reflector and warm load assembly are interposed between the main reflector and feed cluster on every revolution of the antenna to present known and controlled temperatures to the feeds.

The four major antenna elements are:

a) Reflector
b) Feedhorn array
c) Cold sky reflector
d) Warm loads

2.2.4.2 Requirements

The antenna requirements are generated directly by the customer and indirectly are flowed down by Hughes system engineering from other system requirements. Table 2-8 lists the customer requirements for beam efficiencies as well as sidelobe spillover and cross polarization power content. Additionally, the antenna 3 dB beam width is determined from the footprint requirement and the warm load and cold sky reflector return loss is determined from the brightness temperature requirement.

To understand the definitions of the beam efficiencies, sidelobe, spillover and cross polarization power requirements, Figure 2-5 is presented in terms of the angle coordinates about the antenna system. The darkened angular volumes indicate the regions over which the antenna radiation patterns are integrated to determine performance with respect to the requirements. The definitions depicted are as follows:

a. Main beam efficiency is the percentage of the total power contained in an included cone angle of 2.5 times the 3 dB beam width and is centered on the electrical boresight.

b. Main beam plus near sidelobe efficiency is the percentage of the total power contained in an included cone angle of 7.5 times the 3 dB beamwidth and is centered on the electrical boresight.

c. Far sidelobe power is the percentage of the total power over the solid angular region subtending the earth but excluding the main beam plus near sidelobe power.

d. Spillover power is the percentage of the total power contained in the total sphere exclusive of the solid angular region subtending the earth plus the feedhorn spillover (cold sky power).

The sum of these four contributions equals the total power of both co-polarization and cross polarization received by the feedhorn.

e. Feed spillover power is the percentage of the total feed power which is not intercepted by the reflector.

f. Cross polarization power is the percentage of total cross polarization power to the total co-polarization power.

Table 2-8. All antenna susystem requirements are satisfied.

REFLECTOR

	PARAMETER	% POWER
a.	MAIN BEAM EFFICIENCY	$\leq$ 91
b.	MAIN BEAM PLUS NEAR SIDELOBE EFFICIENCY	$\leq$ 96
c.	FAR SIDELOBE POWER	
	[6.6 and 10.76 GHz BANDS]	$\leq$ 0.2
	[18., 21., 37. GHz BANDS]	$\leq$ 0.6
	[54. GHz BAND]	$\leq$ 0.8
	[90. GHz BAND]	$\leq$ 1.0
d.	SPILLOVER POWER (INCLUDES FEED SPILLOVER)	$\leq$ 4
e.	FEED SPILLOVER POWER	$\leq$ 2
f.	CROSS POLARIZATION	$\leq$ 1

FREQUENCY (GHZ)	6.63	10.65	18	21	37	54	90
3DB BEAM WIDTH (DEG)	1.70	1.06	.63	.54	.29	0.32	.16

WARM LOAD AND COLD SKY REFLECTOR

RETURN LOSS $\leq$ -30dB

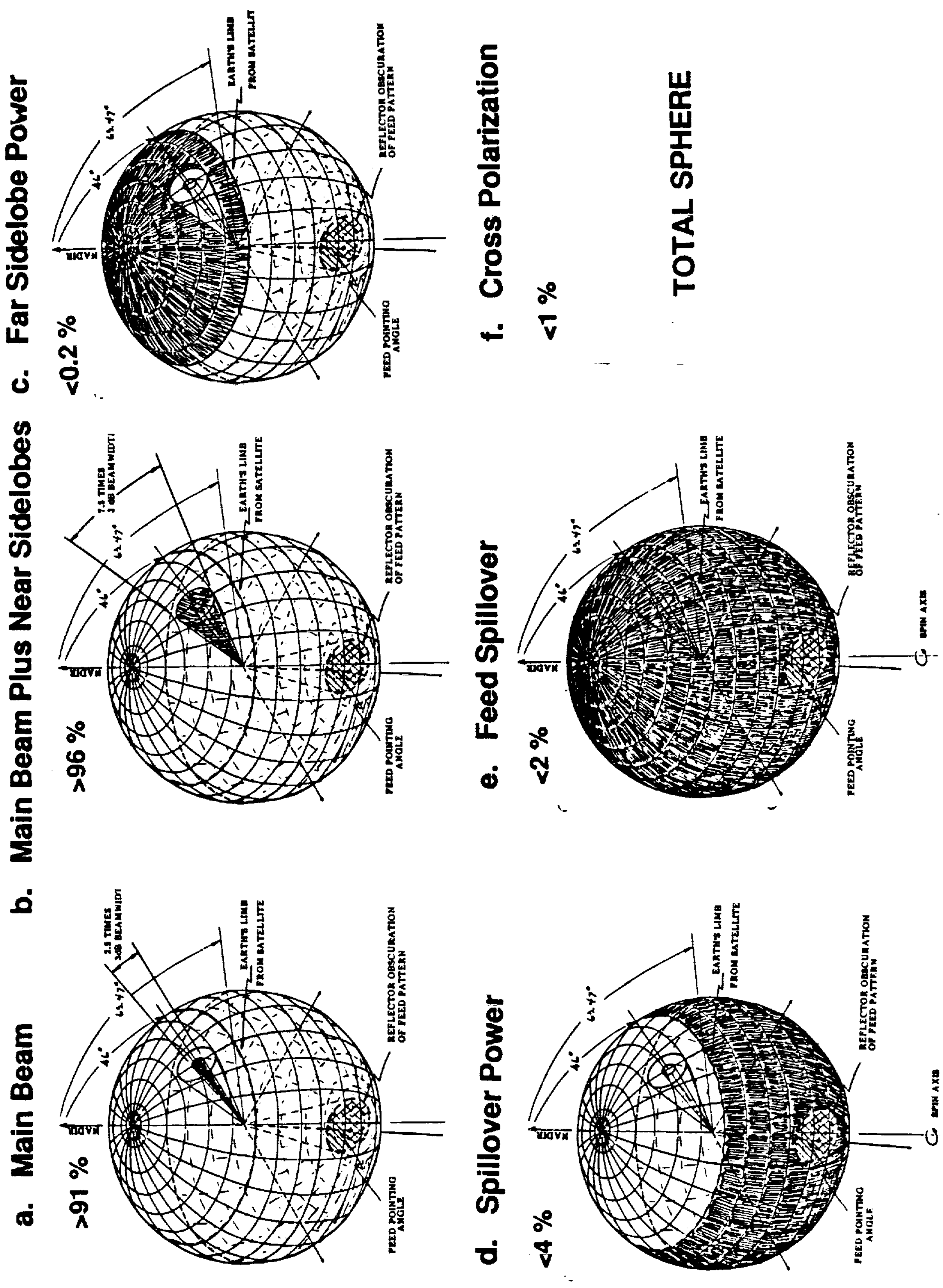


Figure 2-5. Beam efficiencies definitions.

It needs to be pointed out that the determination of the main beam and main beam plus near sidelobes is a relatively simple computation or measurement task due to the small solid angular region involved. But as seen in Figures 2-5 c, d and f, the solid angle involved is increasingly large. Whether computing or measuring radiation patterns over these large angular volumes, small angular increments are required to satisfactorily find the sidelobe contribution. The angular increments become increasingly smaller at the higher frequencies where sidelobe width decreases. For determining the far sidelobe power at 90 GHz, a maximum angular increment of .04 degrees (approximately one fourth of the 3 dB beamwidth) would require 7 million data points to be computed or measured. For the latest and fastest desk top computers something like 24 hours per frequency would be required.

Furthermore, to prove that the far sidelobe power did not exceed 1% at 90 GHz, the algorithm and computational accuracy of an order or two better than 18 bits or a measurement accuracy of an order or two better than 80 dB dynamic range would be required (at 90 GHz the common antenna test range receiver has approximately 40 dB dynamic range).

Therefore, it is concluded that it would be desirable to find arguments for the validity of limiting the angular region over which actual computations and measurements need be made in order to control the program cost. Tutorial and statistical studies of the nature of the reflector patterns hopefully could show that it would not be necessary to integrate over the entire angular volumes defined in the requirements depicted in Figures 2-5 c, d and f. Such a study was beyond the scope of this contract and as such the computations (which required several manmonths of effort) were limited to included conic angular volumes of 15 to 20 times the 3 dB beamwidth without proof of the validity that insignificant energy exists outside of that angular region.

2.2.4.3 Design Trades

In order to define the preferred antenna system which would best meet the design requirements, several trade studies were performed.

The reflector geometry, size and feed illumination characteristics were of prime importance for achieving the design requirements. An offset reflector was selected to avoid aperture blockage caused by the feeds, thus preventing any additional sidelobe degradation. The sidelobe power is controlled by the edge illumination level (relative to the feed radiation pattern peak). Figure 2-6 shows that a low edge illumination of 25 dB below the feed beam peak is required to achieve the design requirements. If only main beam and main beam plus near sidelobe efficiencies were specified, 18 dB edge illumination would suffice. The design driver here is the far sidelobe power. Some margin is required, since Figure 2-6 assumes a perfect reflector surface. To choose an edge illumination lower than -25 dB (very close to the first feed pattern null) is of questionable benefit in that the feed pattern may not be controllable due to small aperture phase errors causing null filling and beam pattern distortions at these low levels. Also, the lower the edge illumination, the bigger the feed horn and reflector have to be to achieve the footprint or 3 dB beamwidth required. A 25 dB edge illumination level was chosen as a suitable compromise.

Having set the edge illumination, the reflector projected aperture diameter is determined.

• FREQUENCY = 6.63 GHz • DUAL MODE POTTER HORN • 85 INCH REFLECTOR

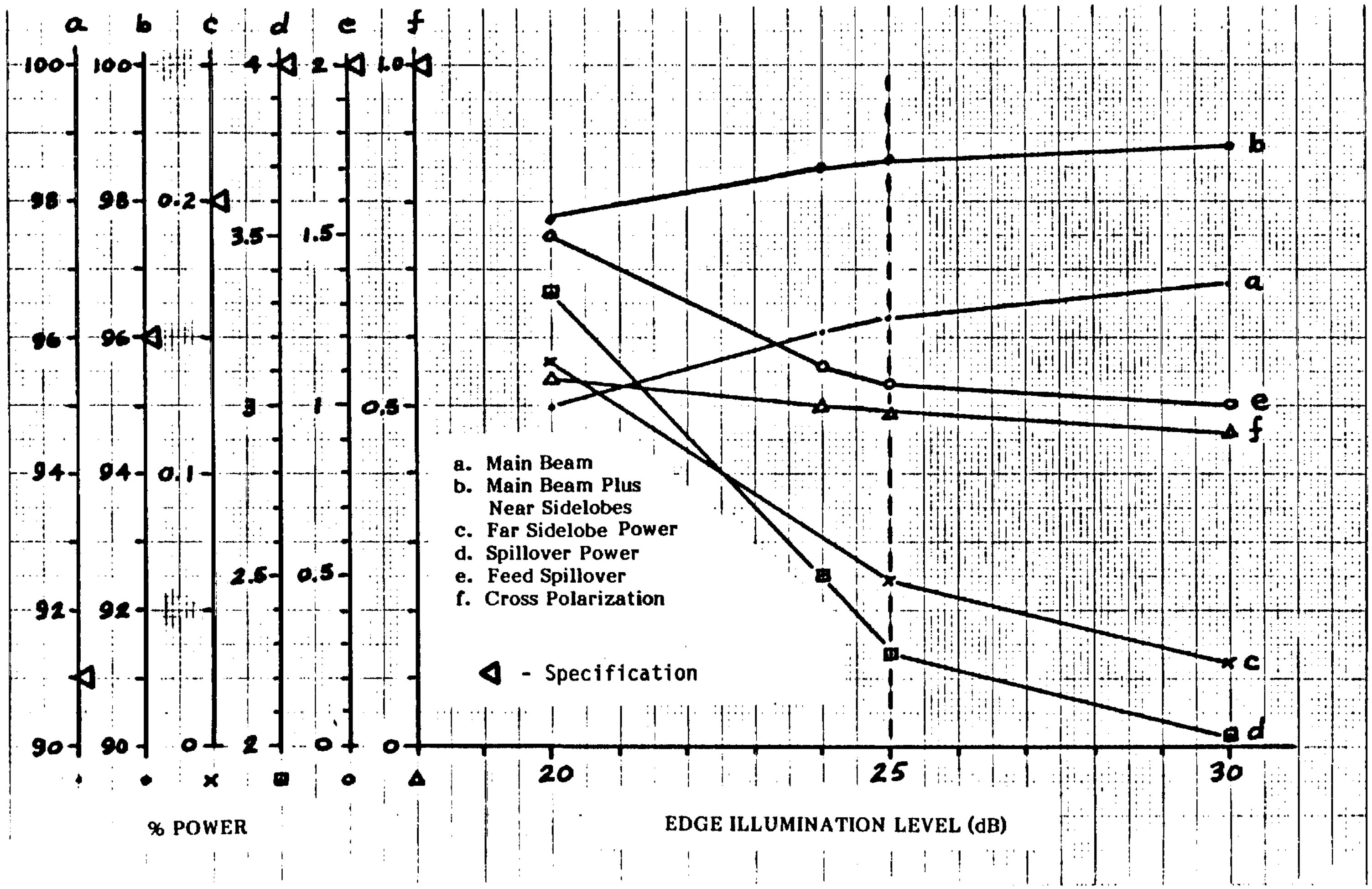


Figure 2-6. Theoretical antenna performance vs. edge illumination level. Edge illumination below 25 dB is necessary to meet the design requirements .

The lowest frequency of 6.63 GHz was used to select the 85 inch diameter to produce the 3 dB beamwidth which meets the 1.7 degree flow down requirement. The choice of the focal length affects the feed horn, warm and cold load sizes as well as the spacecraft integration. Offsetting these considerations is the desire to chose a long focal length which minimizes cross polarization and scan degradations for the feeds which are displaced from the focal axis. Figure 2-7 summarizes the considerations which led to the HIMSS selection for focal length of 61.8 inches.

All of the above work uses a perfect reflector surface simulation in the computation of the antenna performance. It is well known that the presence of imperfections in the reflector surface shape can cause gain loss, beamwidth broadening, sidelobe increase and null filling. It is the sidelobe level and null filling which are most sensitive to surface errors. To a large extent, the presence of systematic manufacturing errors can be compensated for by adjusting the feed location to give the best focusing. Random errors produce a different effect through adding energy to the far out sidelobes as well as the near in sidelobes. Since the far out sidelobes are much lower in level, the random surface errors will cause much more dramatic changes in them. Figure 2-8 shows the results of applying a random perturbation in the reflector surface to cause a .0016 inch rms error from the desired parabolic shape. It is seen that as the frequency is increased, the effect of the error is to cause significant degradation in performance with the greatest impact to the far sidelobe power. It is evident that in order to meet the far sidelobe power requirement, a very exact reflector surface will be required.

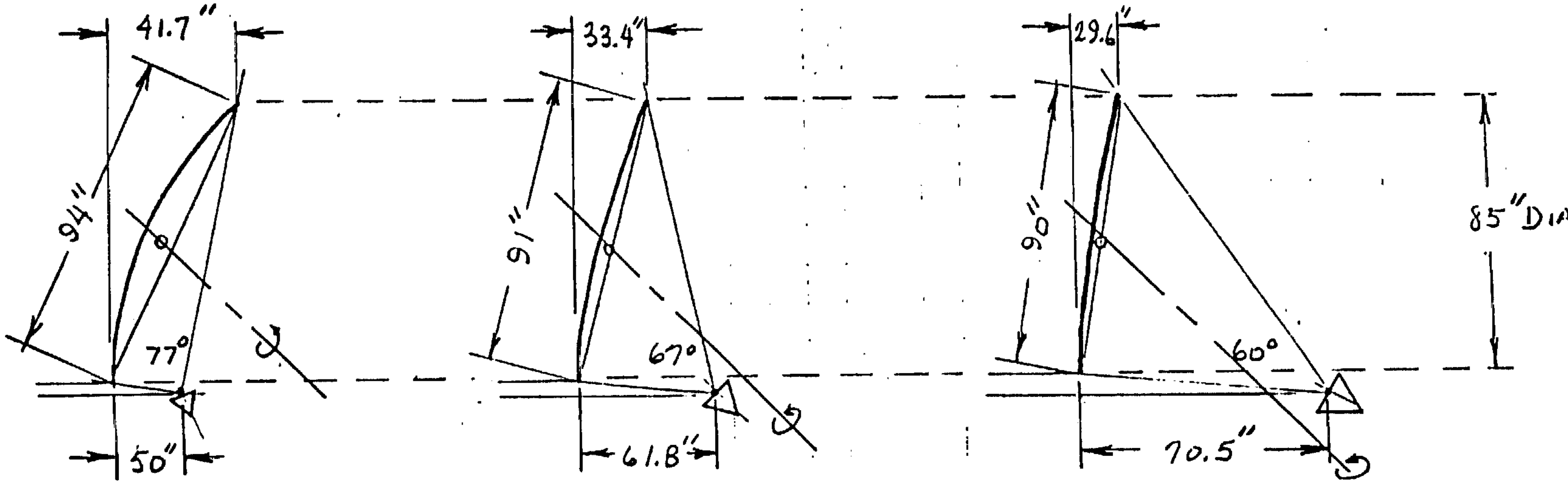
Because of the wide separation between the lowest and highest frequency, a concept with separate feed horns for each band was the selected approach (previous Hughes proposals for other radiometers have had the same conclusions. The placement of these individual feed horns relative to each other could be arranged in many different ways. Three candidate configurations shown in Figure 2-9 were conceived to provide a trade study.

At the outset, each configuration seemed to have an advantage from a particular aspect of the antenna system. The trade study expanded the considerations which led to the observations and conclusions presented in Table 2-9.

The two types of preferred feed horns are corrugated and dual mode (Potter) horns; both produce axially symmetric patterns with low cross polarization. For frequency bandwidths of 10 percent or less, the simpler Potter horn is preferred.

Configuration number 2 has the benefit of reducing the number of feed horns by one. There were sacrifices in performance; however, brought about by the feed pattern variation between 18 and 21 GHz which caused the edge illumination of the reflector to degrade and produced too much sidelobe power. To handle the 18 GHz and 21 GHz frequencies, a corrugated horn was required, which adds to the manufacturing complexity of manufacturing the internal corrugations.

The feed horn cluster in configuration number 3 places each of the feeds with the closest possible location to the focal point of the reflector. This placement actually improved the performance of the 6.6 and 10.7 GHz feed horns. All of the other feeds are located the same as in configuration number 1. The clustered arrangement of configuration number 3 feeds would require significant increased size of the cold sky reflector and potential difficulties finding a clear view to the cold sky.



F/D = .273	F/D = .339	F/D = .385 (SSM/I)
SHORT FOCAL LENGTH	MODERATE FOCAL LENGTH	LONG FOCAL LENGTH
• LARGER STOW VOLUME • C.G. OR FEEDS FARTHER FROM SPIN AXIS • INFERIOR ELECTRICAL PERFORMANCE	"MIDDLE OF THE ROAD" APPROACH	• LARGER/LONGER FEEDS • LARGER COLD SKY REFLECTOR AND WARM LOAD
• SMALLER/SHORTER FEEDS • SMALLER WARM LOAD AND COLD SKY REFLECTOR	HIMSS SELECTION	• SLIGHTLY SMALLER STOW VOLUME • SLIGHTLY BETTER ELECTRICAL PERFORMANCE

Figure 2-7. The three reflector geometries considered for HIMSS.

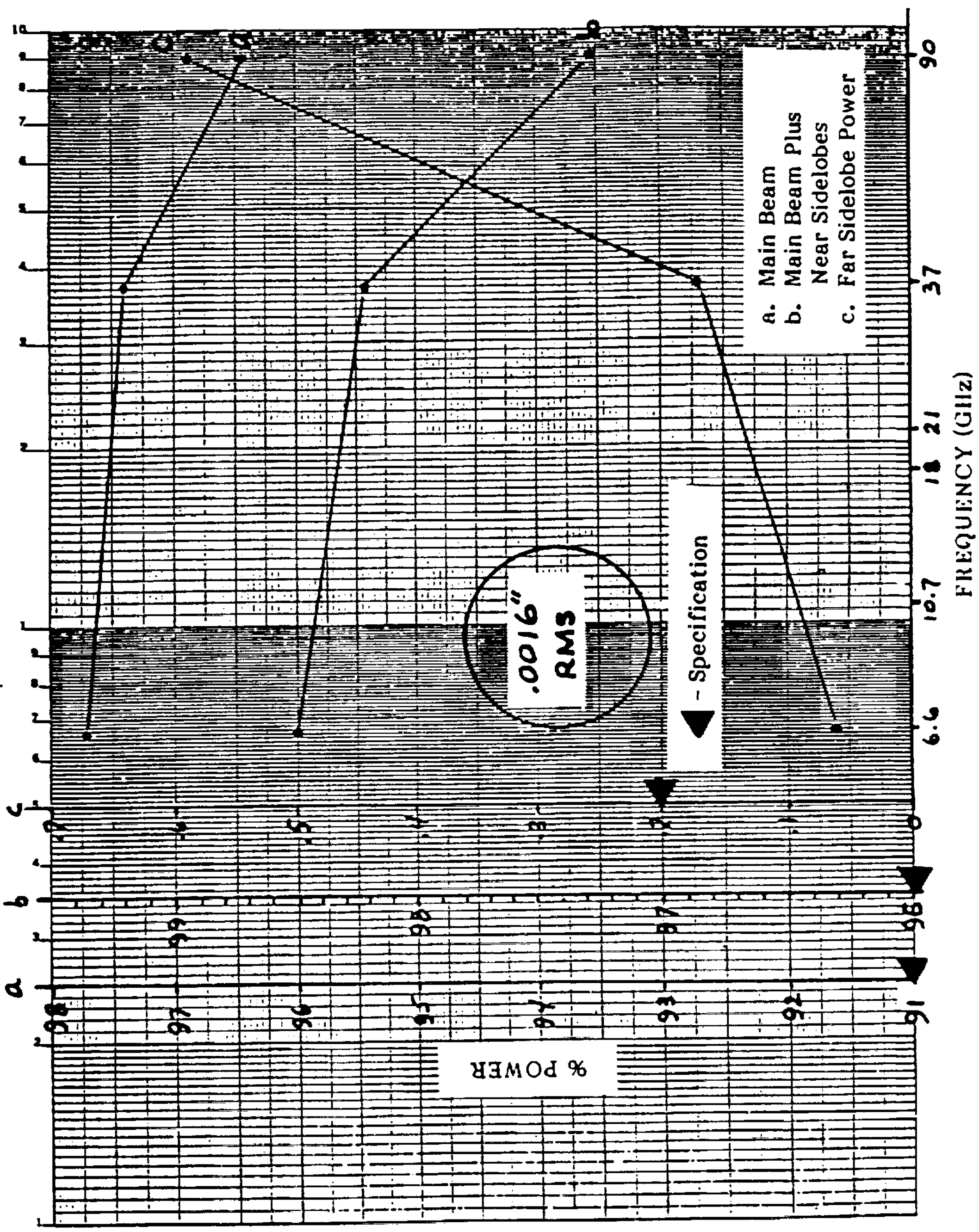


Figure 2-8. The effect of a 0.0016 inch rms error on the surface of the reflector causes degradation in the antenna performance.

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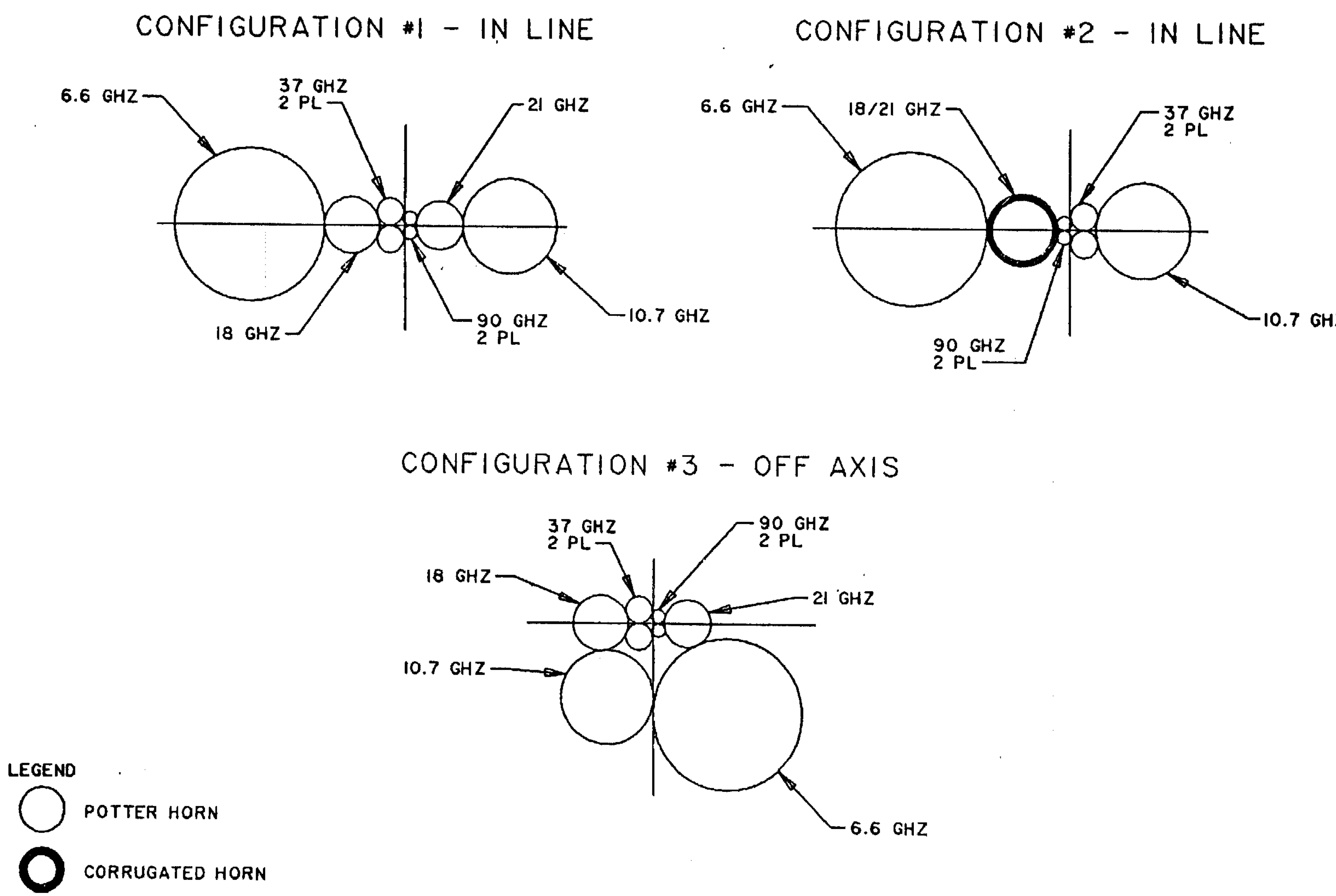


Figure 2-9. Three candidate feedhorn array configurations. Configuration #1 - in-line was considered the baseline.

Table 2-9. Feedhorn array configurations comparison and conclusions.

NO. 1	NO. 2	NO. 3
• IN-LINE, 8 SEPARATE POTTER HORNS	• IN-LINE, 6 SEPARATE POTTER HORNS AND ONE 18/21 GHZ CORRUGATED HORN	• OFF-AXIS, 8 SEPARATE POTTER HORNS
• PRODUCES BEST OVERALL ANTENNA PERFORMANCE	• IMPROVED PERFORMANCE AT 6.6 AND 10.7 GHz	• 18, 21, 37 AND 90 GHz PERFORMANCE SAME AS CONFIGURATION NO. 1 • IMPROVED PERFORMANCE AT 6.6 AND 10.7 GHz
	• DEGRADED 18 AND 21 GHz PERFORMANCE — 300% INCREASE IN FAR SIDELOBE POWER	• SIZE INCREASE FOR COLD SKY REFLECTOR AND WARM LOAD

CONCLUSION: SELECT FEED CONFIGURATION NO. 1

As indicated in Table 2-9 feed configuration number 1 was selected as the best for overall performance and physical considerations.

2.2.4.4 Heritage

The basis for much of the HIMSS antenna design comes from the experience gained on the SSM/I program as well as many study contracts for advanced radiometers.

Because of the differences in requirements, the HIMSS antenna design has differences from SSM/I system. Table 2-10 tabulates the significant features of each design. Notably, the biggest differences are the lowest frequency of operation and the corresponding larger reflector size for HIMSS. The increased number of frequency bands and range has caused the need to use separate feed horns for each frequency band allowing the more stringent performance requirements to be met. The single broadband feed horn used on SSM/I was a good choice for the less stringent efficient requirements and narrower frequency range where larger feed pattern variations are allowable. This is not the case for HIMSS, where each frequency band requires an optimized feed horn design to provide the correct edge illumination.

The warm load design for the absorber coated pyramid dimensions are either an exact replication of the SSM/I (high frequency section) or a frequency scale (low frequency section). See Figure 2-10. Two separate warm loads are required to properly calibrate the broad differences in frequencies between the horns.

2.2.4.5 Design

Figure 2-11 shows a view looking down on the spin axis of the antenna system. This presents a layout of all of the elements of the antenna system. The main reflector and feed cluster are the rotating elements and the cold sky reflector and warm loads are stationary. As the reflector and feeds rotate, the cold sky and warm loads will come between the reflector and feeds resulting in the feeds being blocked from the main reflector. These sectors of the rotation are used to calibrate the radiometer system. The cold sky reflector must limit the energy received by the feeds to that from cold space. Because the feeds of different sizes, the location and shape of the reflector must be compatible for all of the feeds. The warm loads are in two pieces to best serve the low and high frequency horns independently. The high frequency warm load is small, since the high frequency horns are smaller in size, also in contrast to the larger low frequency warm load which serves the low frequency 6.6 and 10.7 GHz. horns.

Figure 2-12 defines the geometry and dimensions for the main reflector, and a preliminary cold sky reflector. More study of the cold sky reflector is required to insure the desired electrical performance. The main reflector design has been optimized along with the feed horn apertures. The reflector is designed as a thermally stable graphite epoxy structure, similar to other Hughes reflectors. The parabolic surface is formed by VDA coated graphite shell, which is backed by a rib support structure incorporating mechanical tuning adjustments. The tuning adjustments are required to achieve a manufacturing surface tolerance better than 0.002 inch rms. The future design and analysis details will address the effects of thermal distortions, centrifugal forces and alignments and tolerances in spacecraft/payload integration. These considerations are important to the electrical

Table 2-10. Comparison between SSM/I and HIMSS requirements points to the differences in the design.

		SSM/I	HIMSS
FREQUENCY	LOWEST	19.35 GHz	6.63 GHz
	HIGHEST	85.5 GHz	90 GHz
	NO. OF BANDS	4	6
REFLECTOR APERTURE SIZE (INCHES)		24	85
FEED SYSTEM TYPE		SINGLE SCALAR HORN	8 POTTER HORNS (1)
NUMBER OF FEED PORTS		7	16
BEAM EFFICIENCIES (%)	a. MAIN BEAM	≥ 87 (2)	≥91
	b. MAIN BEAM PLUS NEAR SIDELOBE	NONE	≥96 (3)
	c. FAR SIDELOBE POWER		≤0.2 (3)
	d. SPILLOVER POWER		<4
	e. FEED SPILLOVER POWER		<2
	f. CROSS POLARIZATION	< 3	<1
COLD SKY REFLECTION APERTURE SIZE		6.8 X 7.6 INCHES	18 X 20 INCHES
WARM LOAD SIZE (INCHES)		4.2 X 4.9 X 0.85	6 X 7 X 2.5 (6.6 AND 10.7 GHZ) 2.75 X 5 X 0.85 (18 TO 90 GHZ)

(1) SEPARATE HORNS REQUIRED FOR BEAM EFFICIENCY SPECIFICATIONS
(2) -18dB EDGE ILLUMINATION
(3) -25dB EDGE ILLUMINATION

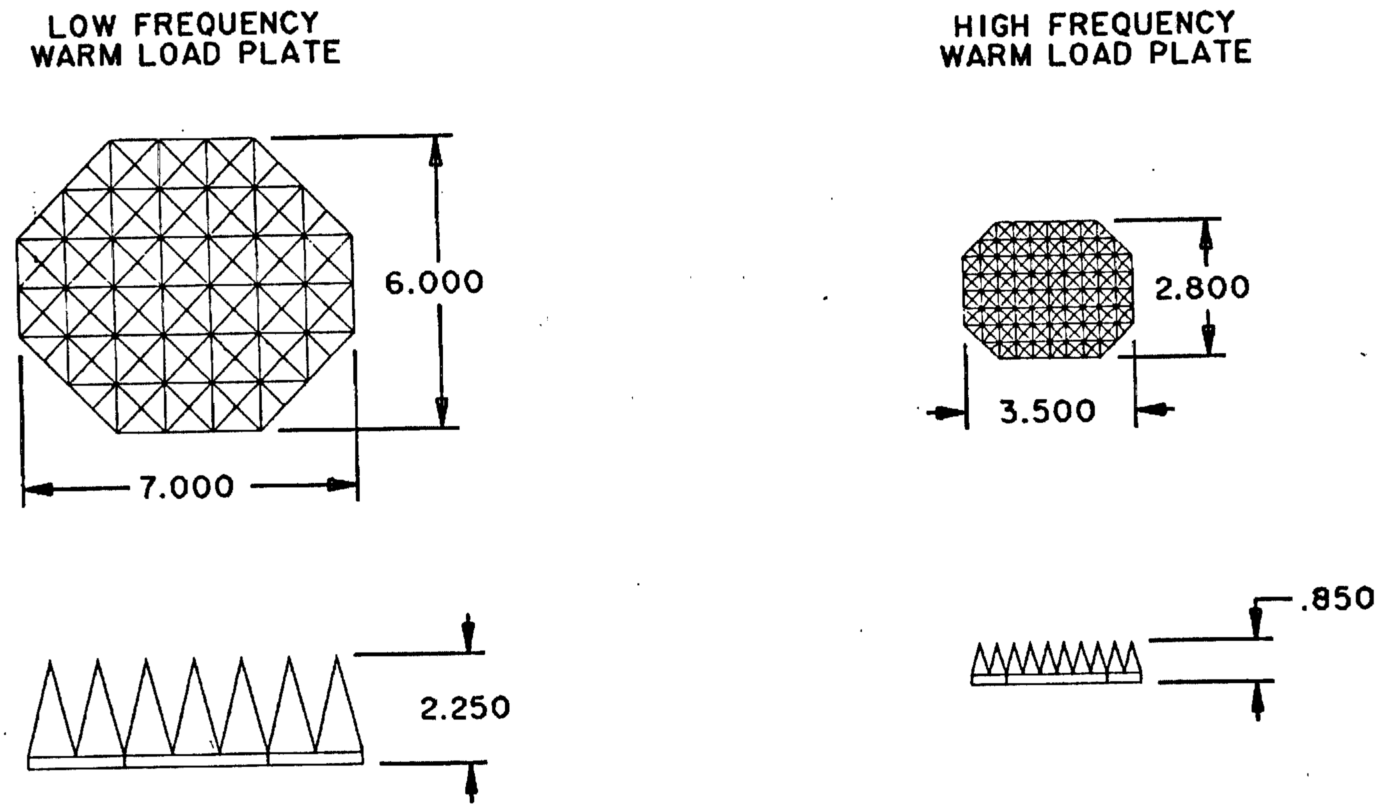


Figure 2-10. Two separate warm loads are required to properly calibrate the HIMSS wide frequency range.

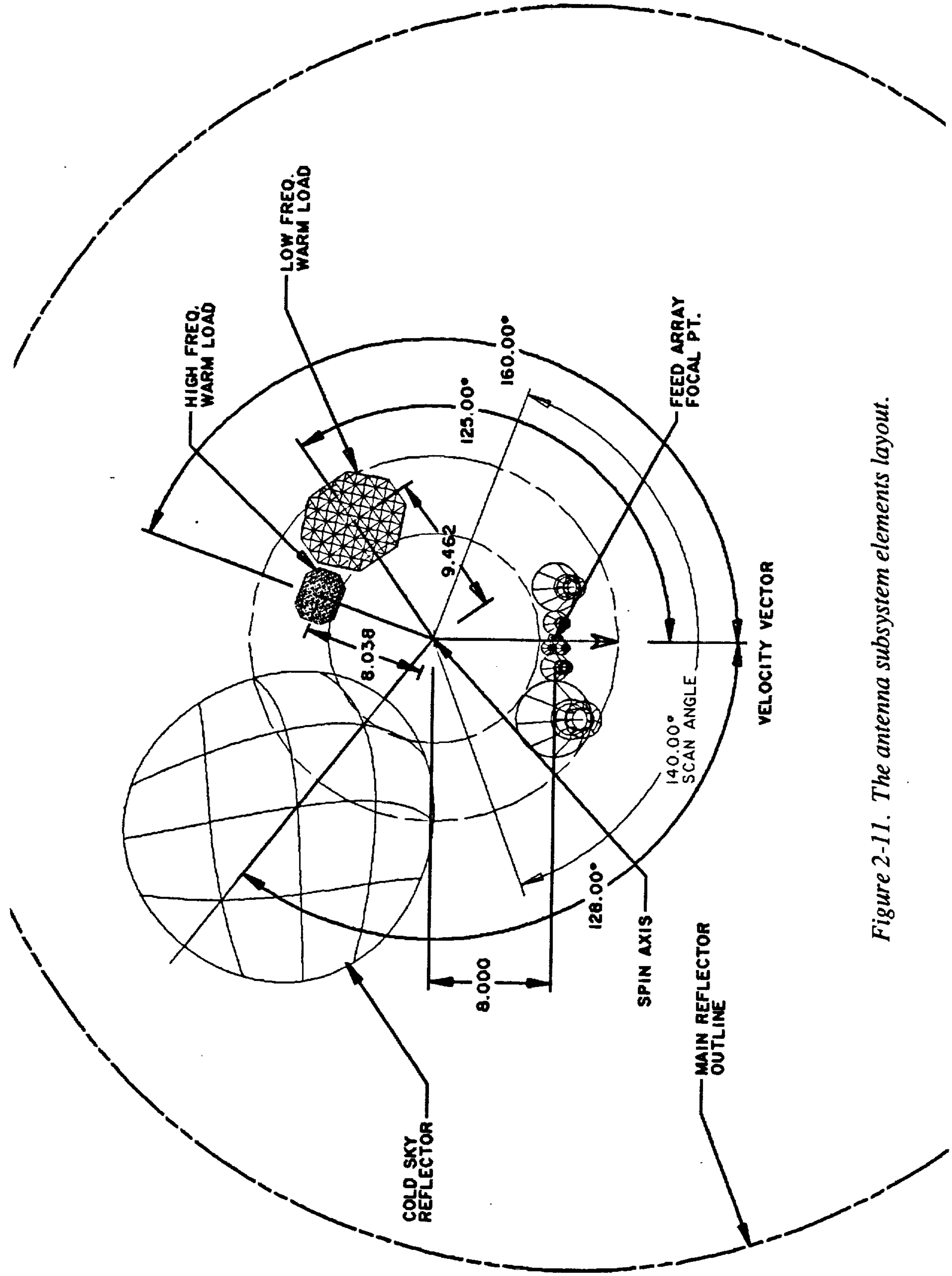


Figure 2-11. The antenna subsystem elements layout.

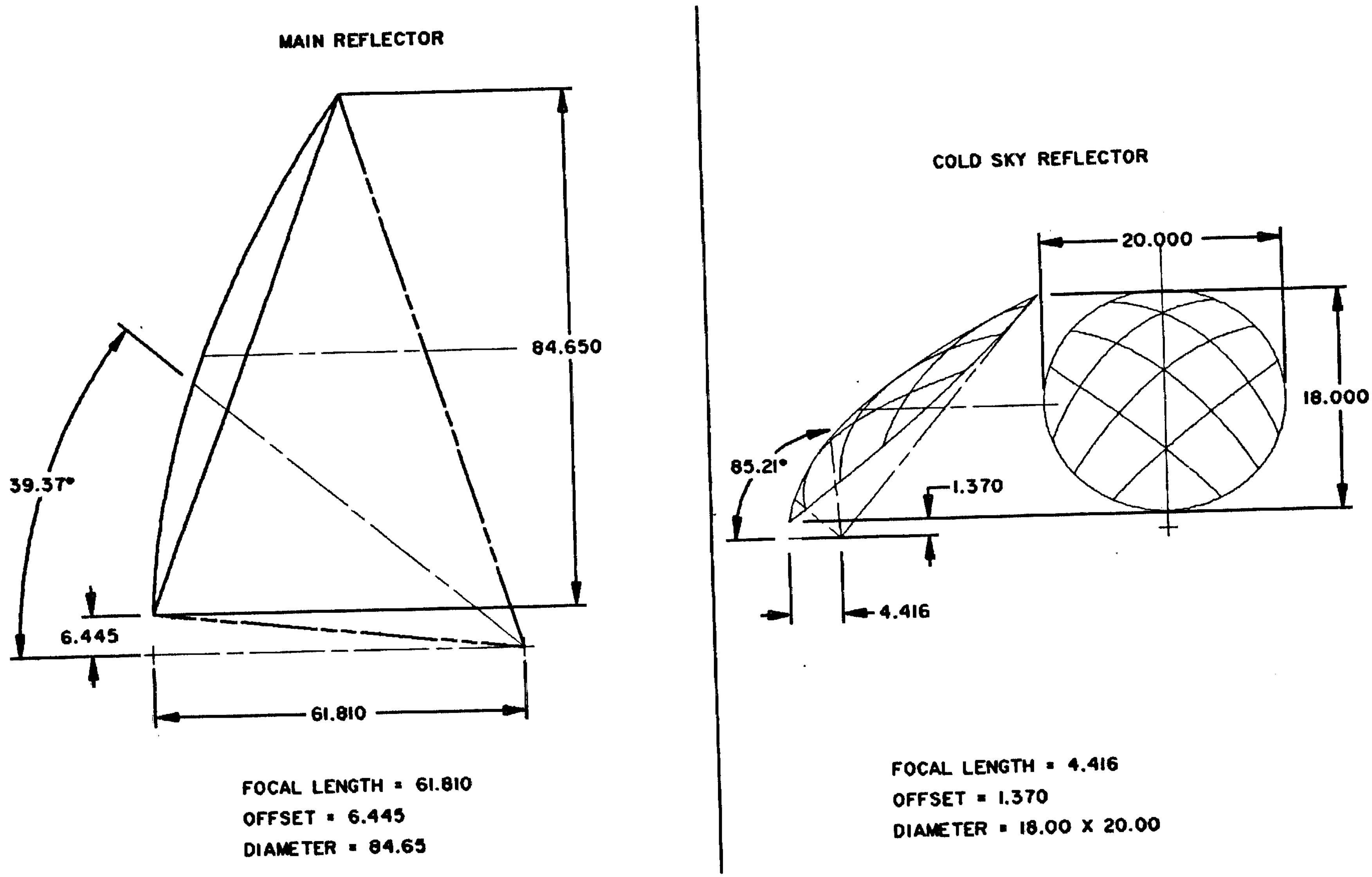


Figure 2-12. The main and cold sky reflector geometries.

performance and are necessary to update the budgeted tolerances used in Table 2-14,p 44.

The feed cluster without the 50-60 GHz feed option is shown in Figure 2-13. The dual mode, Potter horns are depicted with the mode generating steps and orthomode tees which provide the orthogonal linear polarizations for each horn. The low frequency horns are of thin wall machined aluminum manufacture similar to the Hughes built Intelsat VI feed horns. At the highest frequencies (60 and 90 GHz) electroformed copper manufacturing is planned in order to achieve the fine tolerances required.

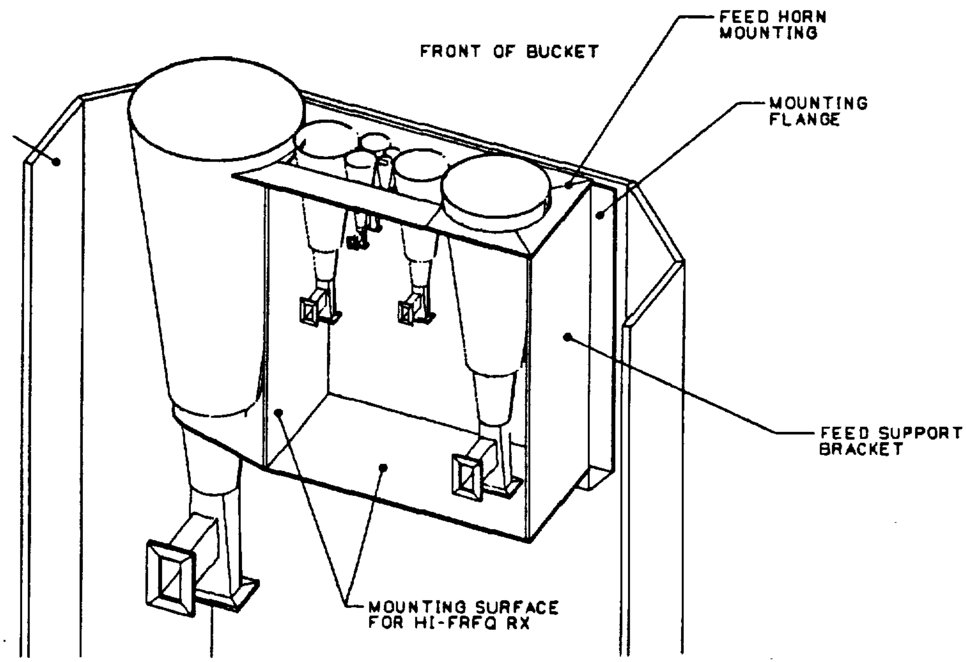


Figure 2-13. Sketch of the feedhorn array as it is mounted in the spinning electronics enclosure ("bucket")

The predicted weights for the elements of the antenna system are tabulated in Table 2-11.

Table 2-11. Estimates of antenna subsystem elements mass.

		MASS, KG.
SPINNING:	REFLECTOR	13.5
	FEEDHORN ARRAY	1.5
DESPUN:	COLD SKY REFLECTOR	2.5
	WARM LOADS	2.5
	SUPPORTING STRUCTUR	0.5
TOTAL		20.5

The performance predictions of the radiometer antenna have been determined by computer simulation.

Two feed options were studied; without and with the 50-60 GHz option. A corrugated horn operating over the 50-60 GHz is inserted into the feed layout with the minimum impact to the performance of the other frequencies. Figure 2-14 compares the two feed arrangements. It is seen that the 37 GHz and 18 GHz feeds incur the greatest increase in displacement in wavelengths from the focal point; 21 GHz, 10.7 GHz and 6.6 GHz have small increased displacements and the 90 GHz feed is the same. The effects of these increased feed displacements are demonstrated in Tables 2-12 and 2-13 (without and with 50-60 GHz option, respectively) and show moderate degradation of the far sidelobe power at 18 GHz and 37 GHz. All other frequencies appear unaffected. The data in these two tables were computed with the assumption of an error free reflector and, as such, provide valid comparisons between the feed options; but additional degradation must be accounted for to obtain more realistic predictions in order to assess the ability to meet the requirements. Although such a detailed evaluation was beyond the scope of this study, information from a previous large reflector radiometer study was used to show what the effects of various contributors could have on the HIMSS antenna performance. Table 2-14 shows the main beam efficiency results of budgeting sources of error in the reflector shape (manufacturing and on-orbit) as well as feed errors (phase center location variations, alignment and frequency bandwidth effects). The past study did not have near and far sidelobe nor secondary pattern spillover requirements, and therefore were not studied. At a more advanced study phase of the HIMSS program, these tolerance effects must be studied to predict the realizable performance for the HIMSS unique requirements. Table 2-15 summarizes the HIMSS study findings.

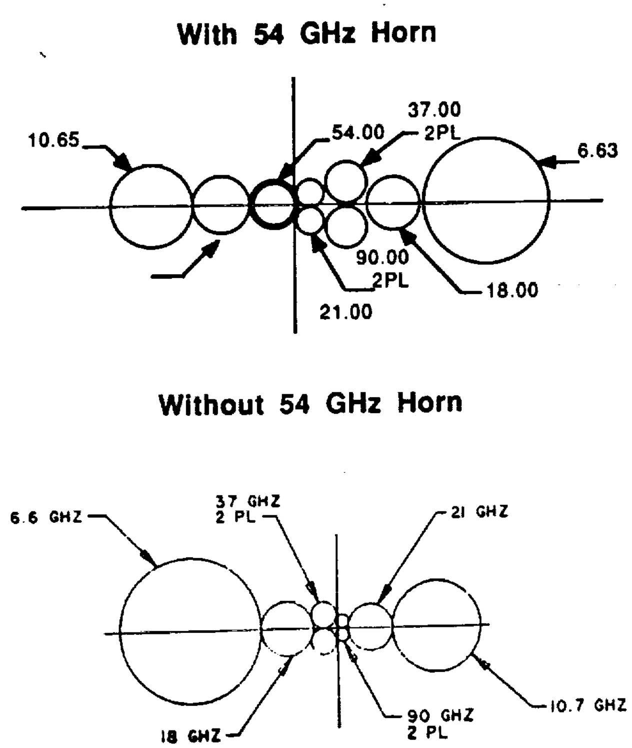


Figure 2-14. Feedhorn array layout with and without the 54 GHz horn (option)

Table 2-12. Estimated theoretical antenna subsystem performance shows margin over the design specification.

**FEED CONFIGURATION NO. 1 (IN-LINE, SEPARATE POTTER HORNS)
REFLECTOR WITH F/D = .339**

		FREQUENCY (GHz)						
	SPEC	6.63	10.65	18	21	37	54	90
a. Main Beam Efficiency (%)	≥91%	96.5	96.5	96.9	97.1	97.6		98.1
b. Main Beam Plus Near Sidelobes Efficiency (%)	≥96%	98.6	98.7	98.7	98.6	98.7		99.0
c. Far Sidelobe Power (%)	SPEC	≤.20	≤.20	≤.60	≤.60	≤.60		≤1.0
	CALC	.06	.06	.04	.07	.04		.08
d. Spillover Power (%)	≤4%	.89	.76	.86	.90	.86		.56
e. Feed Spillover Power (%)	≤2%	.89	.76	.86	.90	.86		.56
f. Cross Polarization Power (%)	≤1%	.49	.46	.43	.43	.43		.32
g. 3dB Beamwidth (Foot Print)	SPEC	≤1.70 (50.3 Km)	≤1.06 (31 Km)	≤0.63 (17 Km avg)	≤0.54	≤0.29 (9.0 Km)		≤0.16 ° (5.0 Km)
h. 3dB Beamwidth (DEG)	CALC	1.70	1.06	0.64	0.53	0.29		0.16

*** ASSUMES PERFECT REFLECTOR AND FEED HORNS**

Table 2-13. Estimated theoretical antenna subsystem performance, with the 50-60 GHz horn added,shows margin over the design specification.

**FEED CONFIGURATION (IN-LINE, SEPARATE POTTER HORNS AND 54 GHz CORRUGATED HORN)
REFLECTOR WITH F/D = .339**

		FREQUENCY (GHz)						
	SPEC	6.63	10.65	18	21	37	54	90
a. Main Beam Efficiency (%)	≥91%	96.53	96.51	96.70	97.08	97.83	98.86	98.24
b. Main Beam Plus Near Sidelobes Efficiency (%)	≥96%	98.56	98.73	98.53	98.61	98.59	99.12	99.01
c. Far Sidelobe Power (%)	SPEC	≤.20	≤.20	≤.60	≤.60	≤.60	≤.80	≤1.0
	CALC	.06	.06	.07	.07	.09	.03	.01
d. Spillover Power (%)	≤4%	.89	.76	.97	.90	.90	.62	.67
e. Feed Spillover Power (%)	≤2%	.89	.76	.97	.90	.90	.62	.67
f. Cross Polarization Power (%)	≤1%	.49	.46	.44	.43	.43	.32	.32
g. 3dB Beamwidth (Foot Print)	SPEC	≤1.70 (50.3 Km)	≤1.06 (31 Km)	≤0.63 (17 Km avg)	≤0.54	≤0.29 (9.0 Km)	≤0.32 (10 Km)	≤0.16° (5.0 Km)
h. 3dB Beamwidth (DEG)	CALC	1.70	1.06	0.64	0.53	0.29	.312	0.16

* **ASSUMES PERFECT REFLECTOR AND FEED HORNS**

Table 2-14. Estimated antenna subsystem performance with reflector shape and feed errors included still meets the design specifications.

		ESTIMATED DEGRADATION FACTOR							BUDGETED TOLERANCES	COMMENTS
FREQUENCY (GHz)		6.63	10.65	18	21	37	54	90		
THEORETICAL		.9653	.9651	.9689	.9708	.9755	.9886	.9810	N.A.	PERFECT ANTENNA
REFLECTOR SURFACE TOLERANCES	RANDOM	.9998	.9995	.9985	.9980	.9938	.9750	.9633	±.002" RMS	ON-ORBIT (MFGR.) AND
	SYSTEMATIC	1.000	1.000	1.000	1.000	.9981	.9985	.9987	±0.10" DEFOCUSING	THERMAL DISTORTION
STRUCTURE DEFLECTION		1.000	1.000	.9998	.9998	.9993	.9985	.9962	±.030" DEFOCUSING	THERMAL, SPIN AND DEPLOYMENT EFFECTS
FEEDS	FREQUENCY BANDWIDTH	.9962	.9993	.9993	.9993	.9993	.9993	.9993	15^0 TO 30^0 PHASE ERROR	APERTURE PHASE ERROR
	PHASE CENTER OFFSETS	.9993	.9988	.9993	.9993	.9993	.9993	1.000	0.2λ DEFOCUSING	90 GHz FOCUSED CO-PLANAR HORNS
POLARIZATION MISALIGNMENT		.9988	.9988	.9988	.9988	.9988	.9988	.9988	$\pm 2^0$	COMBINED FEED-REFLECTOR-PLATFORM
PREDICTED BEAM EFFICIENCY (%)		96.0	96.2	96.5	96.6	96.6	96.0	93.8	≥91% SPECIFICATION	

Table 2-15. The antenna subsystem meets all study rquirements.

ANTENNA EFFICIENCY: • EASILY MEETS 91% OVER 2.5 X 3 dB BEAMWIDTH

> 96% OVER 7.5 X 3 dB BEAMWIDTH

< 4% SPILLOVER POWER

< 2% FEED SPILLOVER POWER

FAR SIDELOBE POWER: • MEETS SPECIFICATION PROPOSED*

< 0.2 % AT 6.63, 10.65 GHz

< 0.6 % AT 18, 21, 37 GHz

< 0.8 % AT 50 - 60 GHz

< 1.0 % AT 90 GHz

* FAR SIDELOBE POWER WILL BE DIFFICULT TO ACCURATELY ANALYZE AND MEASURE
ADDITIONAL ANALYTICAL TECHNIQUE IMPROVEMENTS AND TOLERANCE STUDIES REQUIRED

2.2.5 RECEIVER SUBSYSTEM

2.2.5.1 Elements

The receiver subsystem processes th^ RF signal received from the antenna subsystem and transfers the detected signal to the signal processing subsystem, Figure 2-15. There are separate receivers which cover frequencies from 6.63 GHz to 90 GHz. Each receiver amplifies the RF energy with a low noise amplifier (LNA), (except for the 90 GHz channels, which have no LNA), translates the energy to a lower frequency, filters, and then detects. Detected signals are then passed to the signal processing subsystem via twisted-shielded pair as a balanced signal.

Conditioned and regulated DC power is received from the power subsystem. The DC power is used by all elements of the receiver subsystem.

2.2.5.2 Requirements

Requirements for the receiver subsystem channels are summarized in Table 2-16. The general approach to ensuring compliance with system level specifications has been to establish minimum performance levels, and trade off less critical parameters. For example, the integration time is derived from the sampling rate specification.

Table 2-16. Receiver subsystem requirements.

Specification	Channel Center Frequency (GHz)					
	6.63	10.65	18.00	21.00	37.00	90.00
RF Bandwidth (GHz)	0.34	0.4	0.5	0.5	1.0	1.5
Integration Time (msec) (Derived from Sampling Rate)	3.02	3.02	3.02	3.02	3.02	1.51
Scene Temperature (K)	150	150	300	300	300	300
Required ΔT	0.3	0.3	0.4	0.4	0.4	0.7

2.2.5.3 Design Trades

LNA AND BANDWIDTH. An analysis was performed using the required integration time, scene temperature, delta T and calculated system noise figure to verify the specified RF bandwidth was wide enough for the required delta T to be achieved. Results are presented in Table 2-17.

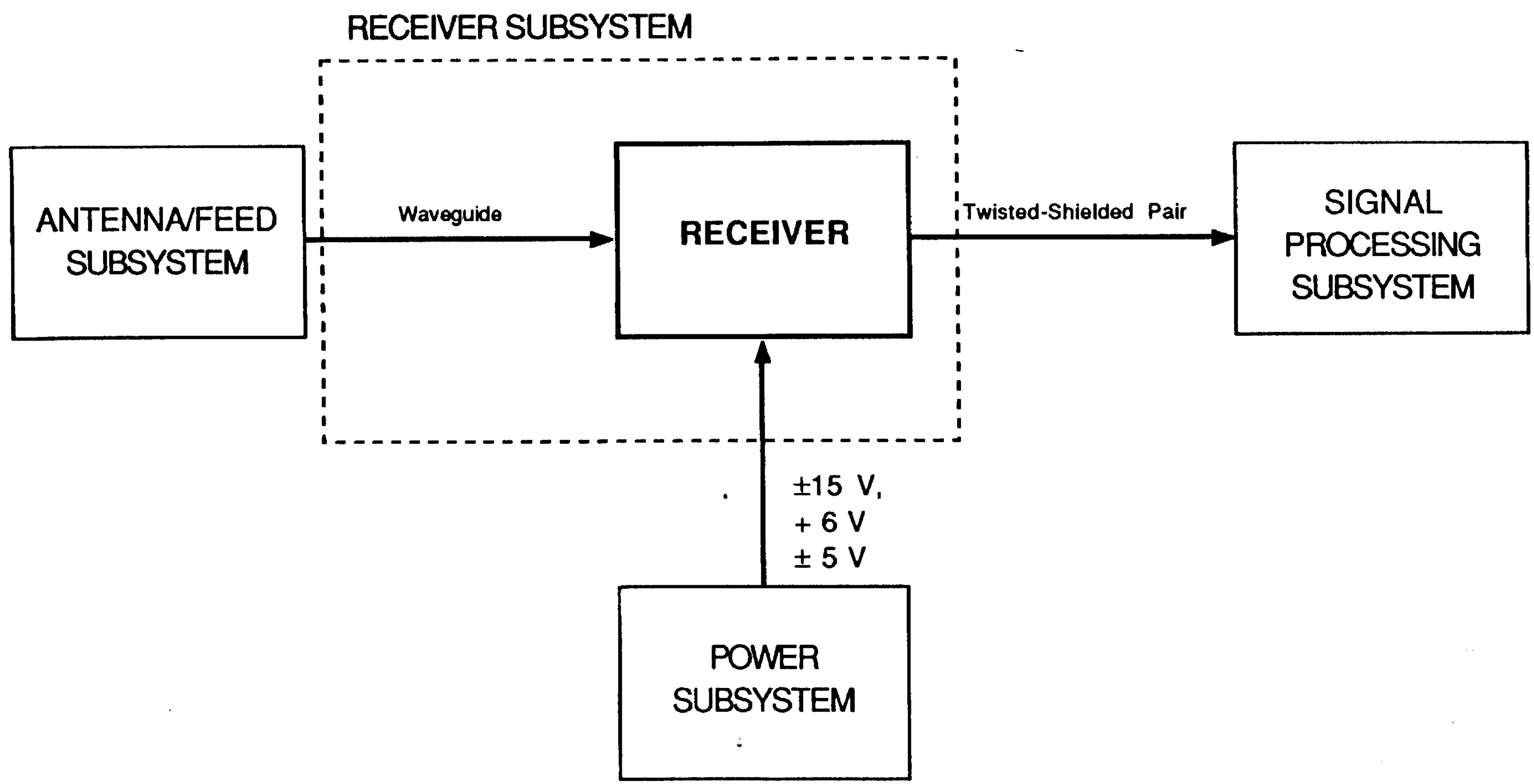


Figure 2-15. The receiver subsystem processes the input from the antenna subsystem and transfers it to the signal processing subsystem.

Table 2-17. Receiver subsystem trade: LNA and Bandwidth. The bandwidth can be achieved only by using LNAs. There are no LNAs at 90 GHz.

COMPONENT	CHANNEL CENTER FREQUENCY (GHz)											
	6.63		10.65		18.00		21.00		37.00		90.00	
	W/LNA	WOLNA	W/LNA	WOLNA	W/LNA	WOLNA	W/LNA	WOLNA	W/LNA	WOLNA	W/LNA	WOLNA
Type of Detection	SSB	SSB	SSB	DSB	SSB	DSB	SSB	DSB	SSB	DSB		DSB
Integration Time (msec)	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02		1.51
Scene Temperature (K)	150	150	150	150	300	300	300	300	300	300		300
Calculated System Noise Figure (dB)	1.8	4.3	2.1	4.0	2.5	4.1[1]	2.7	4.1[1]	3.7	4.2[1]	N A	7.1[1]
(Assumed LNA Noise Figure - dB)	1.4	—	1.6	—	2.0	—	2.2	—	3.0	—		—
Required ΔT	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4		0.7
Resulting Detection Bandwidth (GHz)	.34	1.50	.39	1.3	.57	1.2	.62	1.2	.95	1.25		3.0
Resulting RF Bandwidth (GHz)	.34	1.50	.39	2.6	.57	2.4	.62	2.4	.95	2.5		6.0
Specified RF Bandwidth (GHz)	.34	.34	.4	.4	.5	.5	.5	.5	1.0	1.0		1.5

1 Achieved noise figures on SSM/I program.

Analysis was performed without LNAs and with LNAs to show that an LNA was required to meet the system requirements. Using an LNA, the resulting RF bandwidth was equal to or less than the required bandwidth for the 6.63, 10.65, and 37 GHz receivers. The 18 and 21 GHz receivers require slightly more RF bandwidth. Four times the specified RF bandwidth is required for the 90 GHz receiver, since an LNA is not practical at this frequency. Refer to last two lines of Table 2-18, also, columns in bold type represent the recommended parameters. This wider bandwidth at 90 GHz will not degrade science data retrieval, since the 90 GHz region serves as a window channel. The slightly wider bandwidths at 18 and 21 GHz also will not degrade the science data.

HETERODYNE VS. DIRECT DETECTION. Historically, radiometer receivers have been implemented using a heterodyne architecture. The received microwave energy is frequency translated and detected at the lower frequency. Receivers at frequencies below about 8 GHz can also be implemented using direct detection. Direct detection does not require a frequency translation process. The required RF spectrum is selected by a filter, amplified and applied directly to the detector. HIMSS has chosen the heterodyne approach because it offers the best combination of reliability and proven performance. The heterodyne approach represents the conservative approach. Parameters affecting the detection system are presented in Table 2-18.

There are advantages to be gained by using direct detection. Local oscillators used for frequency translation are heavy and require relatively large amounts of DC power due to their low efficiency. Local oscillators, LOs, are not required for direct detection, thus the power and weight savings. There is also a possible improvement in receiver reliability since the LOs have a relatively high failure rate.

Diode detectors used for direct detection are not flight qualified. Several aspects of the detector circuit need to be optimized, including linearity and temperature stability. The complete detector would then have to be flight qualified.

Even with these "non-recurring" aspects of direct detection, the projected savings in weight and power warrant a more detailed trade-off study.

2.2.5.4 Heritage

Receiver architecture has been strongly influenced by the successful SSM/I design. Increased data acquisition is supplied by two new channels, 6.63 and 10.65 GHz, and LNAs have been added to lower the achieved Delta Ts. Minor modifications in local oscillators and filters are implemented to accommodate the new frequencies for the remaining channels (see Table 2-19).

Table 2-19. HIMSS receiver subsystem uses a modified SSM/I design architecture.

HERITAGE	MODIFICATIONS FROM SSM/I
SSM/I HETERODYNE ARCHITECTURE	- NEW 6 AND 10 GHZ CHANNELS FOR SSTS AND WINDS - LNAS FOR LOWER DELTA TS (< 50 %) - MINOR MODS IN THE COMPONENTS PACKAGING

Table 2-18. Receiver subsystem trade: Heterodyne vs. Direct Detection. The lower cost and risk heterodyne approach was baselined.

	HETERODYNE	DIRECT DETECTION
HARDWARE	• LO's • MIXERS • < 5 GHz DETECTORS	• DETECTOR AT RF FREQUENCY
WEIGHT/POWER	• LO's ARE HEAVY - REQUIRE POWER	• SAVE POWER AND WEIGHT
DETECTOR	• FLIGHT QUALIFIED • FLIGHT EXPERIENCE • DOCUMENTED LINEARITY	• DESIGN EXISTS - NOT FLIGHT QUALIFIED • LINEARITY NEEDS TO BE VERIFIED
RELIABILITY/ RISK	• LO's REDUCE RELIABILITY • LOWER RISK • FLIGHT DETECTOR	• NO L.O. - INCREASED RELIABILITY • DETECTOR NEEDS TO BE QUALIFIED
CONCLUSION: SELECT HETERODYNE APPROACH		

2.2.5.5 Design

6.63 GHz Receiver Block Diagram

A conventional heterodyne approach is implemented for the baseline receiver. The block diagram for the 6.63 GHz receiver is shown in Figure 2-16. RF energy collected by the antenna is separated into the vertical and horizontal polarizations by the orthogonal mode transducer. The desired spectrum is then selected by a bandpass filter, amplified and translated to the IF frequency. Signal processing for both the horizontal and vertical components is identical after the mixer. A bandpass filter selects the difference frequency band, the signal is amplified and a tri-plexer separates the three individual bands of interest.

The three bands are detected and amplified before being transferred to the signal processing subsystem. Note that there are six, 3 vertical and 3 horizontal, simultaneous outputs for the 6.63 GHz receiver.

10.65 GHz Receiver Block Diagram

The block diagrams of the 10.65, 18, 21, and 37 GHz receivers differ from the 6.63 GHz by eliminating the triplexer. The block diagram for the 10.65 GHz receiver is shown in Figure 2-17, and it is representative of the 18, 21 and 37 GHz receivers.

Signal flow and operation is identical to the previous 6.63 GHz receiver with the exception of the number of outputs. These receivers each have two outputs, one for the vertical and one for the horizontal component.

90 GHz Receiver Block Diagram

The 90 GHz receiver differs from the 10.65, 18, 21 and 37 GHz channels in not using an LNA, Figure 2-18. Also, the local oscillator frequency is selected to be identical to the center of the RF band of interest. This reduces the IF filter and amplifier requirements at the expense of system sensitivity.

A second complete 90 GHz receiver is included so the equivalent delta T can be achieved.

50-60 GHz Receiver Block Diagram

Information from five separate RF bands between 50 GHz and 60 Ghz is provided by the 50-60 GHz receiver. Operation is similar to the other receivers and the block diagram is shown in Figure 2-19.

The RF energy is translated to the IF by a single conversion stage and individual channel filters are used to select the energy in the bands of interest. Notice that the two components of channel 22 are selected by filters and then combined at IF. The combined signal is then amplified and detected.

Five channels of detected baseband information are passed to the signal processing subsystem.

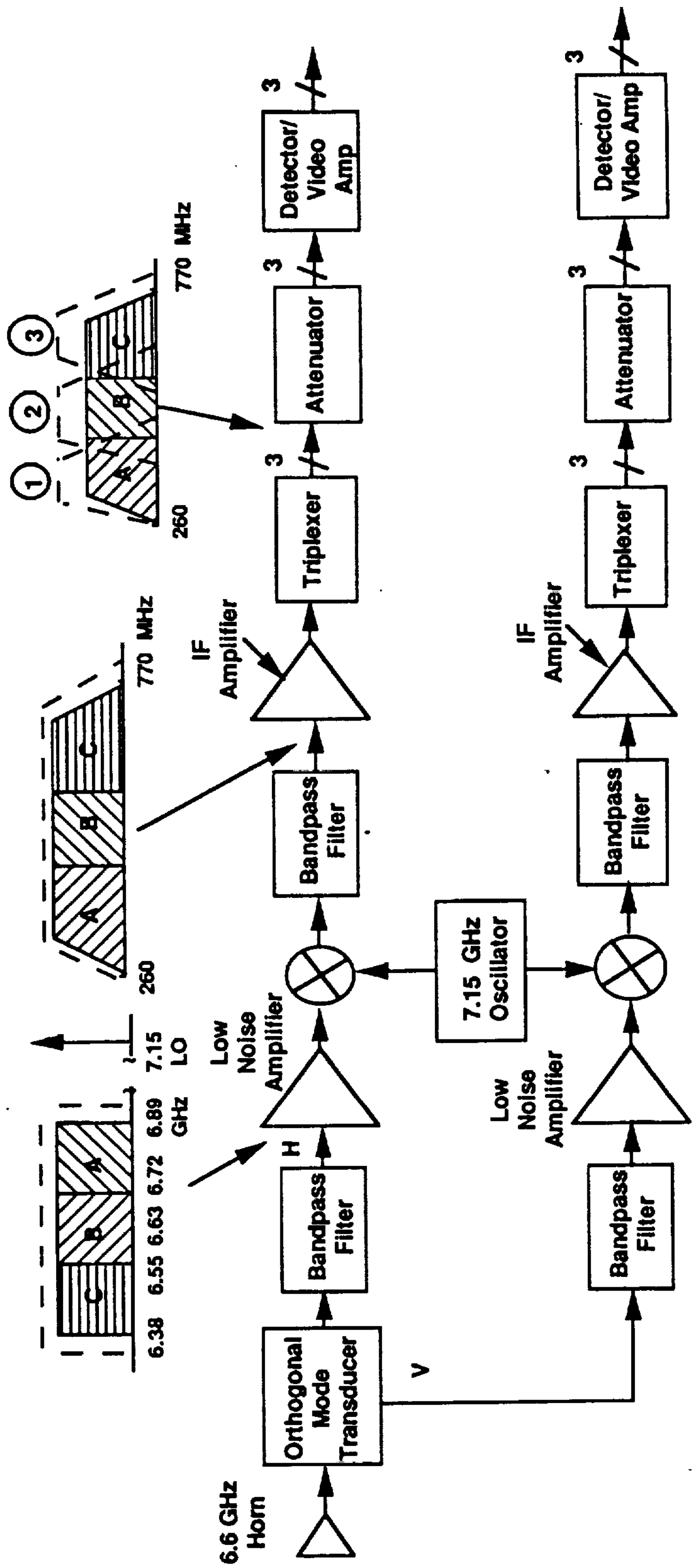


Figure 2-16. 6.6 GHz receiver block diagram

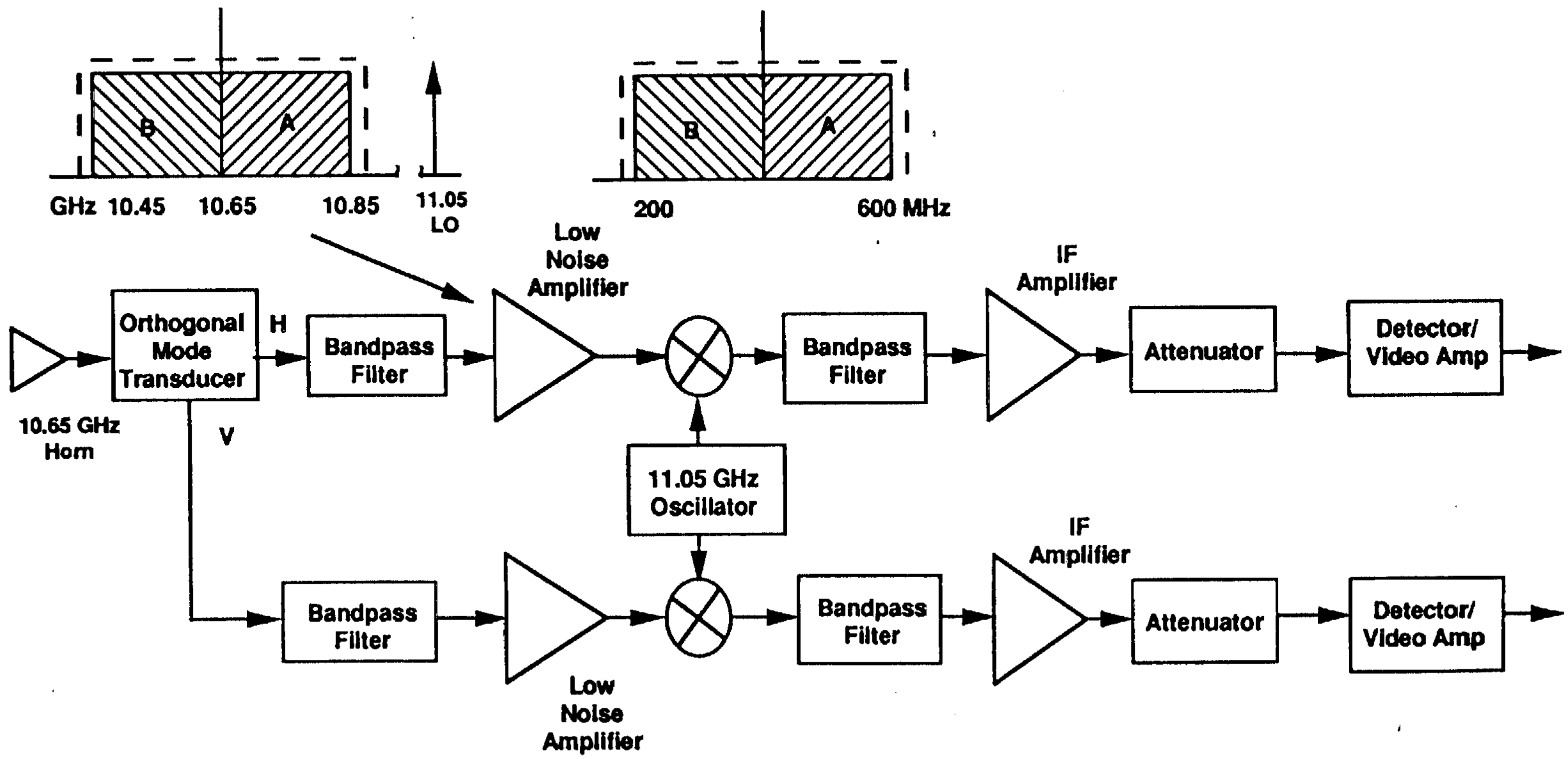


Figure 2-17. The 10.65 GHz receiver block diagram is representative of the 18, 21,and 37 GHz receivers

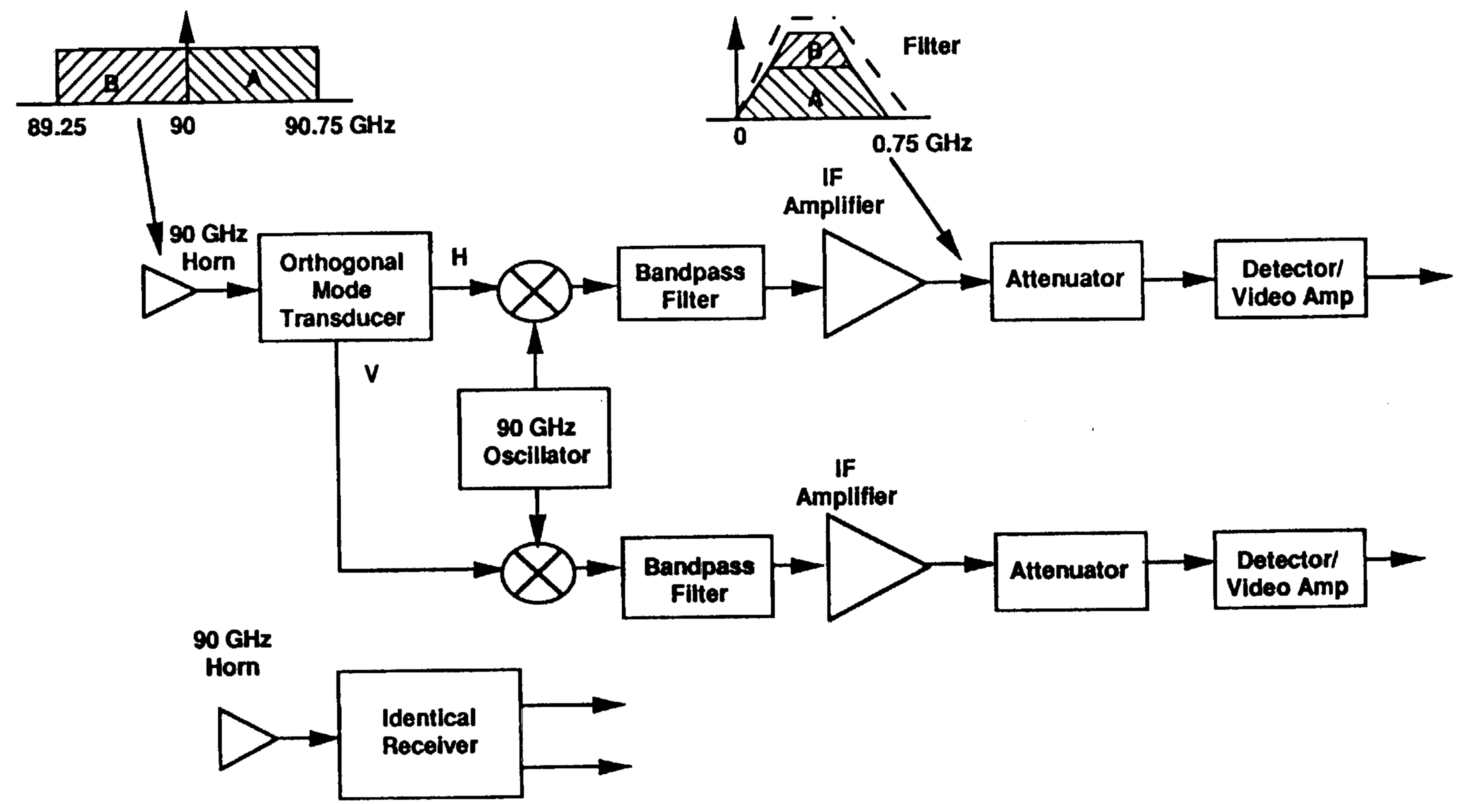


Figure 2-18. The 90 GHz receiver block diagram does not have an LNA.

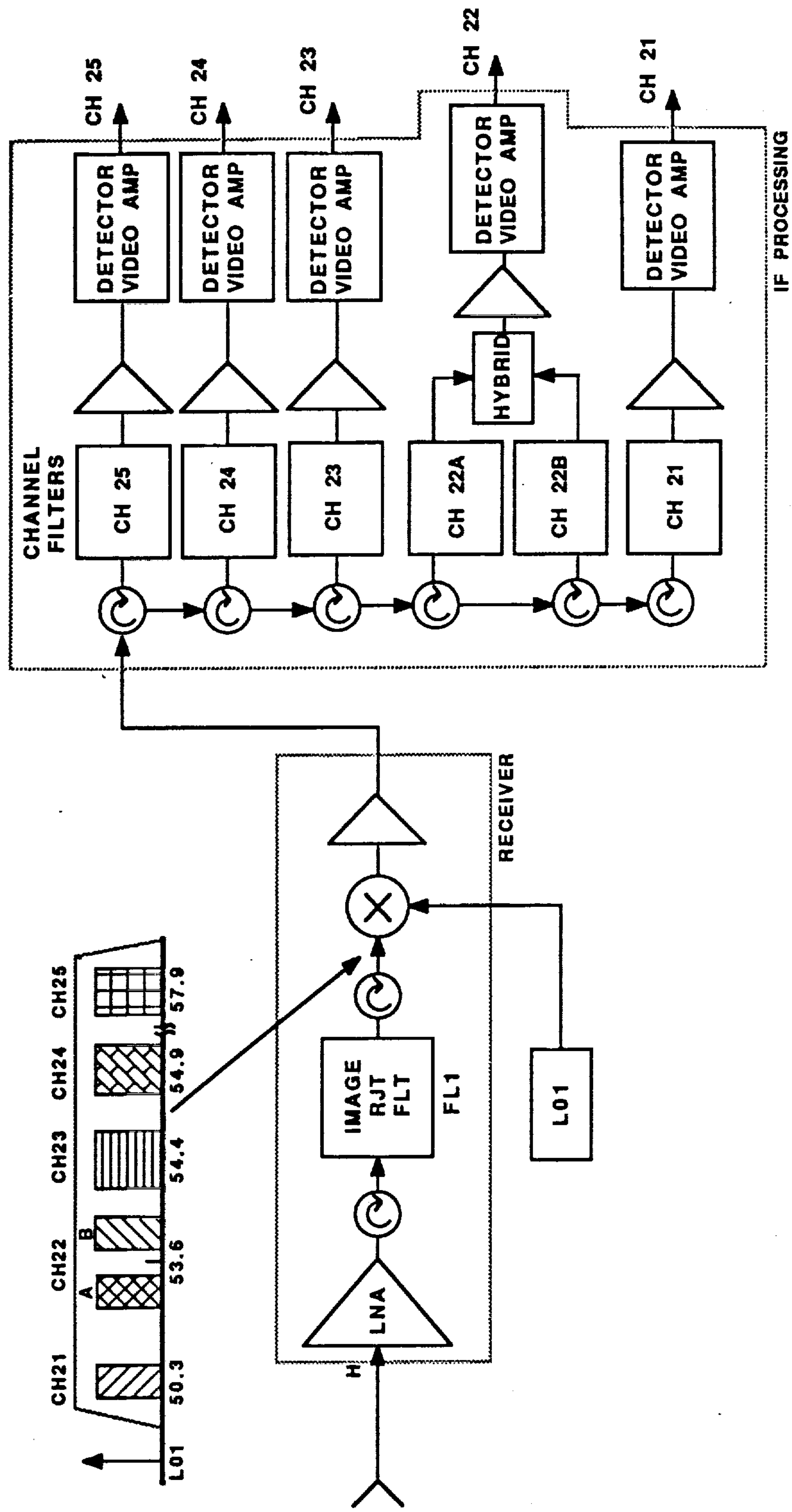


Figure 2-19. 50 - 60 GHz receiver block diagram.

50-60 GHz Receiver Block Diagram - Alternate Architecture

An alternate architecture is presented for the 50-60 GHz receiver, Figure 2-20. The 50-60 GHz signal is separated into H and V polarizations by the OMT. Image rejection filters select the higher frequency channels (23, 24, 25) for the horizontally polarized signal and the lower frequency channels (21, 22A, 22B) for the vertically polarized signal. This reduces the required LNA bandwidth from 8 to 4 GHz, resulting in a lower risk LNA design.

50-60 GHz Channel Bandwidth

As was done for the other channels, we estimated the bandwidth required for the 50-60 GHz channels to achieve the stated integration time, scene temperature, and delta T. The resulting bandwidth requirements generally exceeded the specified values; refer to the last two lines of Table 2-20.

Consultations with Remote Sensing Systems and MSFC have resulted in a decision to use pixel averaging to improve performance in these channels. Allowing for pixel averaging, the required RF bandwidth meets the specification.

2.2.6 SIGNAL PROCESSING SUBSYSTEM

2.2.6.1 Elements

The signal processing subsystem consists of a single non-redundant signal processing unit. The major elements of this unit are signal processing amplifier hybrids, an analog multiplexer, an analog-to-digital converter, and an application specific integrated circuit (ASIC).

The amplifier hybrids process the incoming differential analog signals from the receiver subsystem and provide single-ended signals to the analog multiplexer for analog-to-digital conversion. These amplifiers provide 16 levels of variable gain control based on the cold and warm load temperatures during each scan. They also provide an integrate-and-dump function for noise filtering purposes.

The analog multiplexer performs time-division sampling of all science data from the receiver subsystem and analog instrument status. This multiplexer is implemented with 16-channel CMOS monolithic circuits that have been used on several past Hughes programs.

The analog-to-digital converter does a 12 bit conversion of each analog sample received from the analog multiplexer and transfers the resulting digital data to the ASIC. This converter uses hybrid technology and has previously been used on Hughes' HS601 programs.

The ASIC is a custom VLSI (very large scale integration) circuit that does all the logic timing and control functions for the unit. It is implemented with silicon-on-sapphire CMOS technology and manufactured at Hughes' Microelectronics Technology Center in Carlsbad, California.

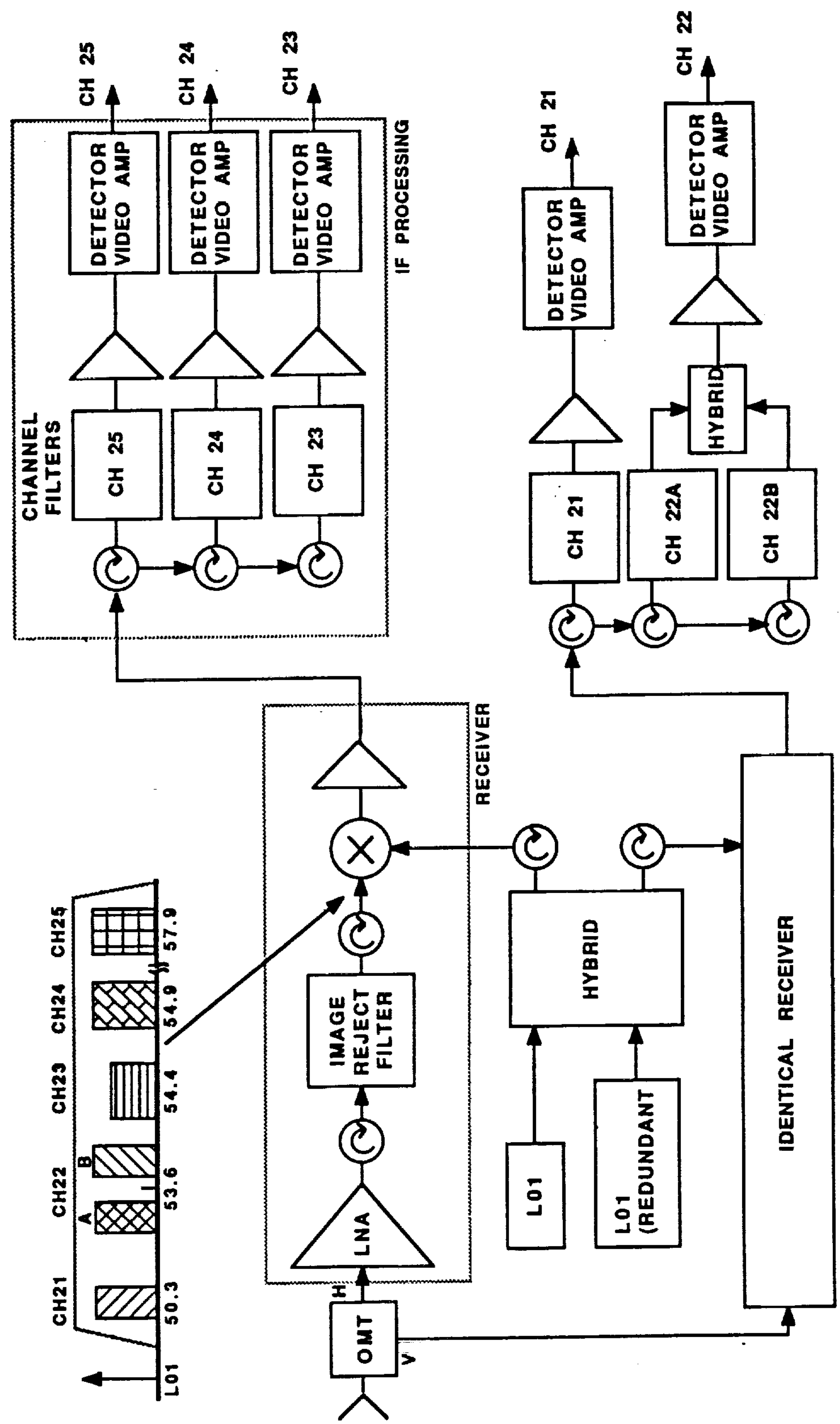


Figure 2-20. An alternate architecture for the 50 - 60 GHz receiver.

Table 2-20. Estimated 50 - 60 GHz receiver performance. Pixel averaging is necessary in order to meet the design specifications.

Channel Number	21	22	23	24	25
Channel Center Frequency (GHz)	50.3	53.6	54.4	54.9	57.9
Type of Detection	SSB	SSB	SSB	SSB	SSB
Integration Time (msec)	3.02	3.02	3.02	3.02	3.02
Effective integration with pixel averaging (msec)*	12.08	12.08	12.08	12.08	12.08
Achievable System Noise Figure (dB)	4.08	4.08	4.08	4.08	4.08
Required ΔT	0.5	0.5	0.5	0.5	0.5
Resulting Single Polarization Detection Bandwidth (GHz)	0.75	0.75	0.75	0.75	0.75
Resulting Single Polarization Combined RF Bandwidth (GHz) without Pixel Average		0.375			
Resulting RF Bandwidth with Pixel Averaging (GHz)	0.188	0.188	0.188	0.188	0.188
Specified RF Bandwidth (GHz)	0.200	0.340	0.400	0.400	0.400

* 4 Pixel Averaging Performed by Ground Software

2.2.6.2 Requirements

The signal processing subsystem satisfies all performance requirements over a five year service life with a 98 percent probability of success. Total radiation dose at the internal semiconductor chips is expected to be less than 50,000 rads (Si) for this life-time and orbit. Components used in the Signal Processing Unit design can generally tolerate dose levels one-to-two orders of magnitude greater than this.

A key set of signal processing subsystem requirements relate to video data processing. The subsystem is required to multiplex 20 differential data channels from the receiver subsystem for the baseline and 25 data channels when the 50-60 GHz channel option is included. The subsystem provides 16 levels of input signal gain control based on cold and warm load measurements performed during each scan. Offset compensation is provided to null out receiver subsystem noise offsets. Receiver subsystem signals are integrated, held for analog-to-digital conversion, and dumped before the start of the next sample. Each video data sample is converted to a 12 bit digital word and temporarily stored within the signal processing unit during each scan. The stored data are then formatted and transferred to the spacecraft payload science bus as serial PCM telemetry data. This science data stream meets the interface requirements specified in the General Instrument Interface Specification for the Eos Observatory.

In addition to video science data, the signal processing subsystem is required to process other HIMSS instrument status telemetry. This telemetry includes six warm load platinum temperature sensors, the antenna deployment angle, the signal processing unit temperature, 16 instrument status analog channels, and four bilevel digital status bits. The instrument status analog channels include instrument temperatures and momentum unbalance. The bilevel status bits indicate ON/OFF status of the instrument's motor, receivers, maintenance heater, and warm-up heater.

The signal processing subsystem provides processing of eight bit serial commands received from the spacecraft's redundant bus data units. The signal processing unit uses these commands to generate up to eight discrete pulse commands for instrument use. Required pulse commands identified thus far include warm-up and maintenance heaters on, motor driver and reference clock on, and warm-up heater off and receivers on.

The signal processing subsystem generates a number of clock signals for use by the power subsystem and BAPTA control electronics (BCE). A 384 kHz reference clock is provided to the power subsystem to synchronize the DC-to-DC converters contained in that subsystem. Other timing signals provided for the BCE use include a 30 Hz spin reference frequency, a 3 kHz modulation synchronization frequency, and a 15 kHz clock.

Table 2-21 summarizes the HIMSS instrument data handling requirements for both the baseline and 50-60 GHz channel option. A spin rate of 40.6 RPM and an active (picture-taking) scan angle of 140 degrees result in an active scan period of 0.575 second. The active scan period is the time of each spin cycle during which science data from the receiver subsystem is sampled and processed. Table 2-21 shows the number of words required to support each complete scan of data along with the resulting average bit rate for both the baseline and the 50-60 GHz channel option.

The number of picture data words shown in Table 2-21 is based on channel integration times of 1.51 milliseconds for each of the 90 GHz channels and 3.02 milliseconds for each of the other channels. Calibration data words are based on five cold load samples and five warm load samples for each antenna horn. Gain data represent 4-bit codes for each channel signifying one of 16 gain levels used during scan sampling. Status telemetry represents analog, bilevel, and time code data associated with the status of the HIMSS instrument. The time code represents the time difference between input data sample and time of output transfer to the spacecraft. This time difference in conjunction with spacecraft time code data (provided in the spacecraft's downlink telemetry frame containing the science data) allows the ground station to determine actual time of sample.

Table 2-21. Data handling requirements for both the baseline and the 50 - 60 GHz option.

SCAN PARAMETERS

SPIN RATE	40.6 RPM
SPIN PERIOD	1.48 SECONDS
ACTIVE SCAN ANGLE	140 DEGREES
ACTIVE SCAN PERIOD	0.575 SECONDS

DATA HANDLING (PER SCAN)	BASELINE 12-BIT WORDS	OPTION 12-BIT WORDS
PICTURE DATA	4564	5514
CALIBRATION DATA	80	90
GAIN DATA	7	8
STATUS TELEMETRY	18	18
PACKET HEADERS	36	44
	4705	5674
AVERAGE BIT RATE	38.2 KBPS	46.1 KBPS

2.2.6.3 Design Trades

A trade-off study was conducted to consider use of a microprocessor versus a hard-wired logic controlled system. The conclusion reached from this study is that the hard-wired logic approach is better for the HIMSS application. The microprocessor chip set considered in the trade study implements the MIL-STD-1750A architecture. Additional interface logic implemented on an ASIC (application specific integrated circuit) would be required to support the microprocessor. On the other hand, all the required logic functions could be implemented on a single ASIC, thus reducing the Signal Processing Unit's parts count. The microprocessor approach requires additional PROM (programmable read-only memory) to store the software as "firmware", thus increasing power consumption by 0.5 watt. Reliability is higher for the single ASIC approach due to lower parts count. The most significant disadvantage of the microprocessor approach is the added software development cost.

Another trade-off study was conducted to consider the use of hybrid component technology to implement the variable gain amplifiers and integrate/hold/dump functions. Conclusions reached are that there are major advantages to use hybrids as opposed to discrete components and therefore this approach was selected. Use of hybrids saves 700 parts resulting in a weight and volume savings of 3 kilograms and 3450 cubic centimeters, respectively. Non-recurring cost is reduced due to lower unit product design cost. Per unit recurring cost is also lower due to less manufacturing hands-on labor.

2.2.6.4 Heritage

The architecture of the HIMSS signal processing subsystem is derived from the SSM/I program. Signal processing techniques used are similar to those used on SSM/I except that these techniques are implemented in an application specific integrated circuit (ASIC) rather than through use of a microprocessor as was done on SSM/I.

Where appropriate, circuit functions used on previous Hughes programs are proposed for HIMSS. One example is the analog multiplexer that is implemented with 16-channel CMOS monolithic circuits used on several Hughes programs including HS261, MMB, and HS601. Another example is the analog-to-digital converter that uses hybrid technology and has previously been used on Hughes' HS601 programs.

HIMSS modifications from SSM/I include expanding the number of science data channels from 7 to 20 (or 25, including the 50-60 GHz option) and various circuit modifications to accommodate the Eos spacecraft telemetry and command interfaces and replace obsolete parts.

2.2.6.5 Design

Figure 2-21 shows all the electrical interfaces that exist between the signal processing unit and the spacecraft or other HIMSS instrument subsystems. Interfaces with the spacecraft are completely redundant. They include a three-wire serial command port from spacecraft Bus Data Units and redundant differential science data outputs from the Signal Processing Unit that interface with the spacecraft's MIL-STD-1553B low rate payload science bus.

The signal processing unit receives power in the form of three regulated DC voltages (+15 volts, -15 volts, and +5 volts) from the power subsystem and provides a 384 kHz clock to synchronize the power subsystem's DC-to-DC converters. Twenty differential video data channels (25 for the 50-60 GHz channel option) are received from the receiver subsystem. Antenna deployment angle potentiometer telemetry and six warm load platinum temperature sensor inputs are received from the antenna subsystem. The signal processing unit receives a master index pulse (MIP) signal from the bearing and power transfer assembly (BAPTA) for determining picture start-of-scan. The unit outputs a 30 Hz spin reference frequency, a 3 kHz modulation synchronization signal, and a 15 kHz clock signal for use by the BAPTA control electronics (BCE). The signal processing unit provides discrete output pulse commands for HIMSS instrument use and collects analog and discrete bilevel telemetry from other HIMSS subsystems.

The signal processing unit receives serial commands from the spacecraft's redundant bus data units in order to generate discrete pulse commands required by other HIMSS subsystems. This three-wire interface, shown in Figure 2-22, consists of command data, clock, and enable. The signal processing unit logically "ANDs" the 128 kHz continuous clock with the enable signal to form a gated clock that is used to serially shift the command data word into the unit. Although figure 2-22 indicates an eight bit command message length, longer command words can be accommodated. Bits 4, 5, and 6 are decoded to select one of eight discrete pulse command output lines. The trailing edge of the enable signal is used to trigger a one-shot within the signal processing unit that is used to time the selected pulse command output. Bit 7 provides odd "1" parity on the entire command word

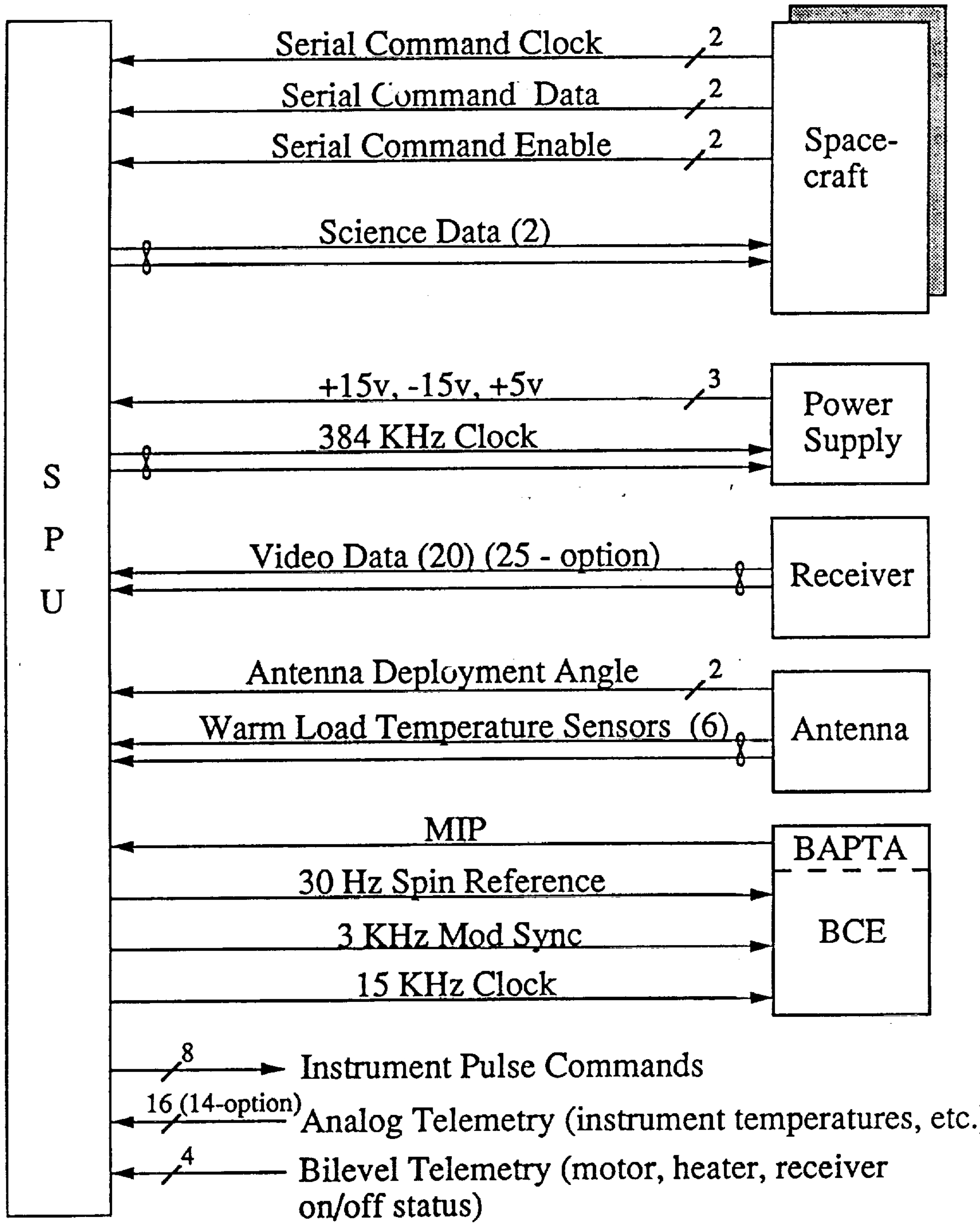
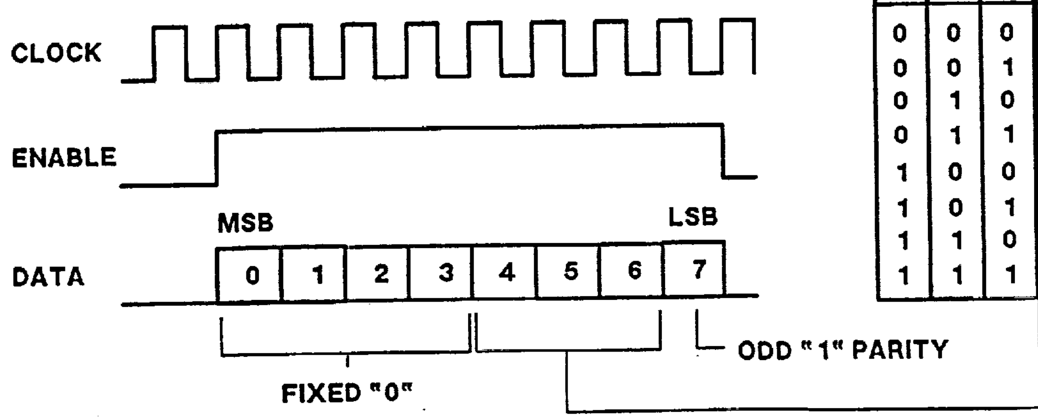


Figure 2-21. Signal processing unit interfaces with all the other HIMSS units and with the observatory



4	5	6	PULSE COMMAND
0	0	0	0
0	0	1	1
0	1	0	2
0	1	1	NOT USED
1	0	0	NOT USED
1	0	1	NOT USED
1	1	0	NOT USED
1	1	1	NOT USED

Figure 2-22. HIMSS/observatory command interface.

in order to provide a simple error check of the received command message. The signal processing unit rejects commands with incorrect parity. The unit telemeters command accept/reject status in its output science data stream.

The signal processing unit formats the HIMSS science data and instrument status telemetry into data packets compatible with the low rate science data requirements specified in the General Instrument Interface Specification for the Eos Observatory. Average data rates for the baseline and 50-60 GHz channel option are 38.2 kbps and 46.1 kbps, respectively. The signal processing unit burst transfers each data packet at a 1.048 Mbps rate to the spacecraft's payload science bus using redundant MIL-STD-1553B transformer coupled data buses. As illustrated in Figure 2-23, each data packet consists of a 48 bit packet header followed by 6144 data bits. Each block of 6144 data bits represents 512 twelve bit signal processing unit words, which are equivalent to 768 eight bit spacecraft words.

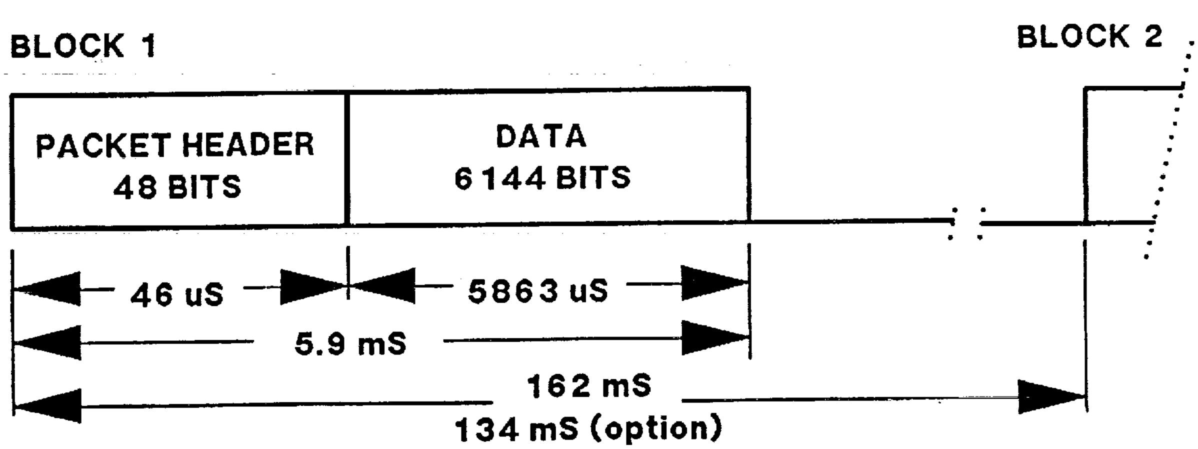


Figure 2-23. HIMSS/observatory science data interface.

Figure 2-24 shows a block diagram of the signal processing unit. Amplifier hybrids receive the science video data from the receiver subsystem and provide the proper gain levels and signal integration. Outputs from these amplifier hybrids are time division multiplexed to a 12-bit analog-to-digital converter. Other analog data representing instrument status, warm load platinum temperature sensors, antenna deployment angle, and an internal signal processing unit reference voltage and thermistor are also multiplexed and digitized.

A single ASIC (application specific integrated circuit) implements the timing and control for the entire unit. Input data sampling sequences and output formatting parameters are stored in PROM (programmable read-only memory). Sampled and digitized science and status data are temporarily stored in RAM (random access memory) before being read out on the MIL-STD-1553B payload science data bus for transfer to the spacecraft.

The signal processing unit processes and decodes serial commands received from the observatory bus data units. The unit uses the serial commands to generate up to eight discrete command outputs for use by other HIMSS subsystems.

The MIP signal is received from the BAPTA and is used to determine the start of each picture scan. The signal processing unit generates clock signals for use by the BCE and the power subsystem.

2.2.7 POWER SUBSYSTEM

The power subsystem receives power from the observatory bus and distributes it to the momentum wheel assembly (MWA) and, after regulation, to all the sensor electronic assemblies.

2.2.7.1 Elements

There are three elements in the power subsystem:

a) preconverter,
b) bias power supply, and
c) post-regulator.

1. Preconverter. This assembly converts the incoming observatory bus, 120V to a 52V distribution bus. High speed switching technology with field effect transistors (FET) is used for compact size, weight and efficiency. The 52V output is regulated within +/-5%.
2. Bias power supply. The 52V regulated bus from the despun sections is transferred to the spun section through the electric contact ring assembly (ECRA). The bias power supply provides the required output voltages to the various electronic assemblies, e.g., +28V, +15V, -15V, +6V, +5V. This assembly also includes the dual heater switch for warm-up and maintenance heaters. The bias power supply further provides voltages to the post-regulator assemblies.
3. Post-regulator. The post-regulators receive the different voltages from the bias power supply and provide the same voltages with fine regulation to the RF subsystem. The assembly also has a sequence controller to apply and remove the voltages in a prescribed manner.

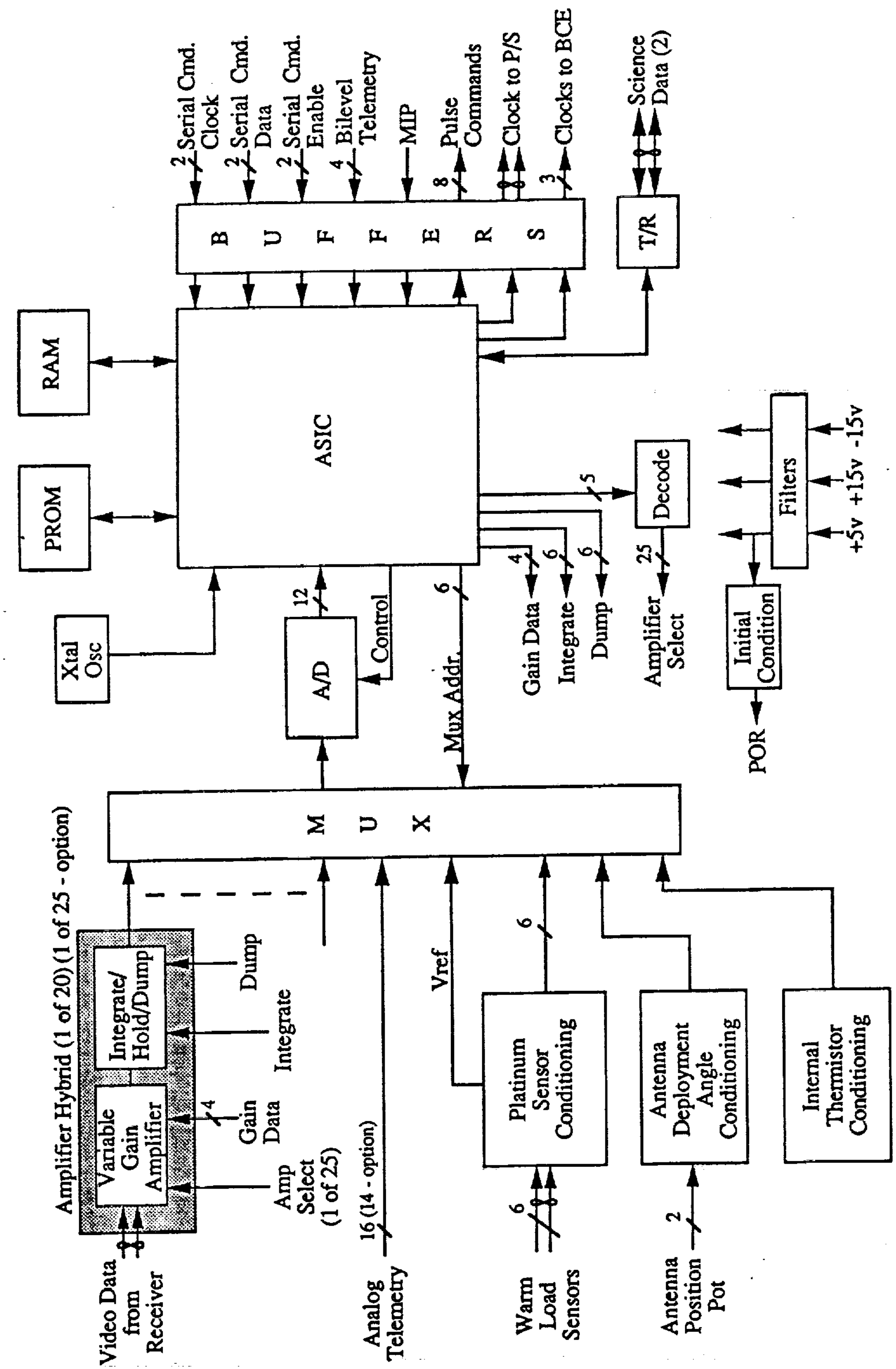


Figure 2-24. Signal processing unit block diagram.

2.2.7.2 Requirements

2.2.7.2.1 Bus Voltage

The nom:nal Eos bus voltage shall be 120V with +4% long term D.C.variation.

2.2.7.2.2 Bus ripple

The bus ripple shall not exceed 5% pk-pk of the nominal bus voltage. The lowest and the highest bus voltages, including long term D.C. variation, and the ripple shall be 109.2V and 130.8V respectively as shown in Figure 2-25.

2.2.7.2.3 Bus Transient

The maximum bus transient shall be 24V above or below the nominal bus voltage of 120V. The duration of the transient shall not exceed 10 milliseconds.

2.2.7.2.4 In-rush Current

Shall not exceed 50 mA per microsecond.

2.2.7.2.5 Voltages and Currents

The power subsystem voltages and current requirements with and without the 50-60 GHz option shall be as defined in Table 2-22.

2.2.7.2.6 Power Distribution

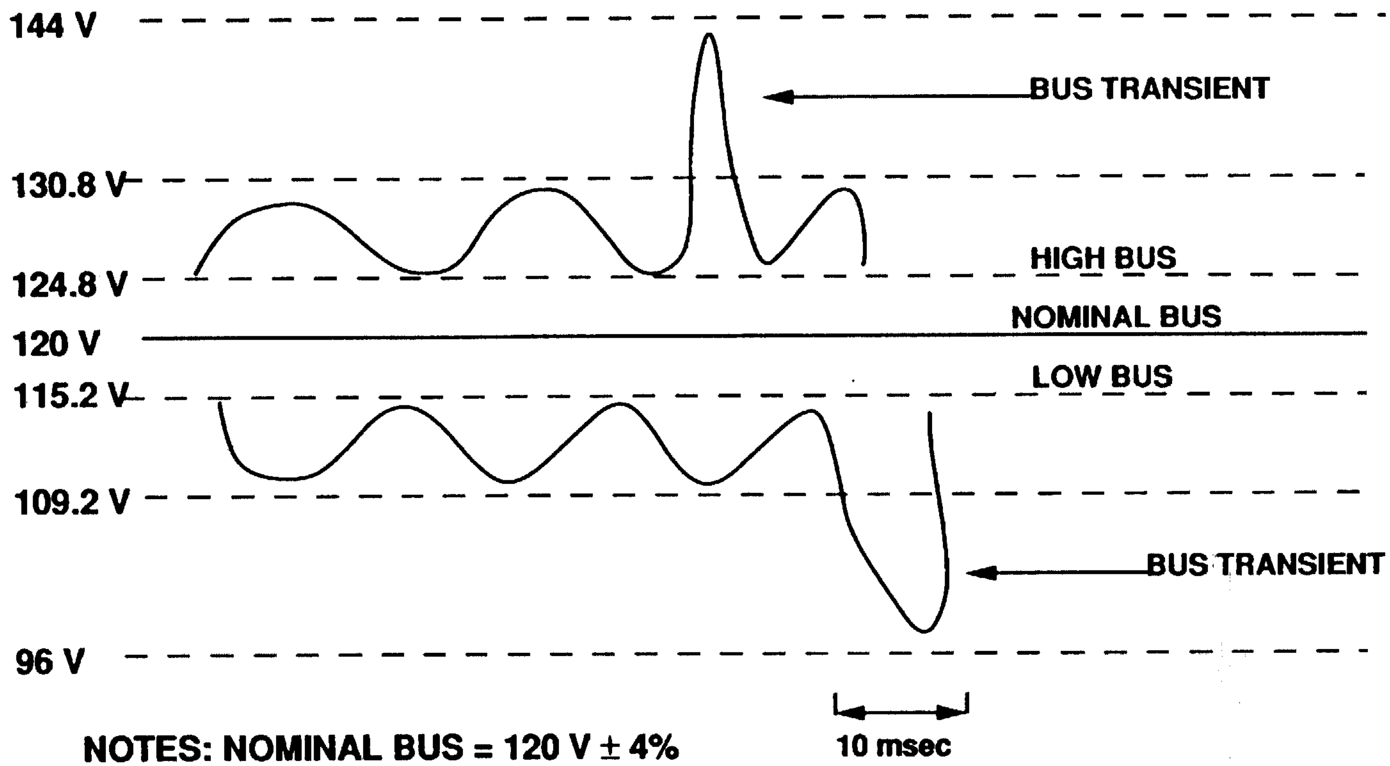
The despun and spun sections power distribution shall be as per Figure 2-26. The preconverter shall generate the main 52V distribution bus feeding the bias power supply element through the ECRA. The bias power supply shall generate +28V, +15V, +5V, +16V, +7V and +6V. The +7V is fed to the post-regulator element to provide fine voltages to the Gunn oscillators. The +6V, +16V are also fed to the post-regulator assembly to provide finely regulated +5V and +15V for the LNAs and IF amplifiers-detectors.

The +15V and +5V from the bias power supply are used by the BAPTA control electronics, speed control unit and the signal processing unit.

The momentum wheel assembly (MWA) receives power from the 52V bus before the ECRA transfer. The bias power supply provides power at 28V to the heaters.

2.2.7.2.7 Telemetry and commands

The telemetry and commands lists are shown in Tables 2-23 and 2-24.
There shall be no ON/OFF commands to the preconverter. The power subsystem is turned ON when the obsevatory provides the 120V bus to the instrument.



NOTES: NOMINAL BUS = 120 V ± 4%
RIPPLE = ± 2.5%
TRANSIENTS : HIGH = 144 V
LOW = 96 V
DURATION <10 msec

IN-RUSH CURRENT = 50 mA/micro sec

Figure 2-25. The Eos bus characteristics showing transients and ripple.

VOLTAGE REGULATION	+5V ±1%	6V ±40mV reg.	-5V ±3%	+15V ±3%	-15V ±3%	+28V ±7%	52V ±1%
RECEIVER	240 (320)	1900 (2300)	100 (120)	780 (1030)	120 (200)		
SPU	440 (1200)			220 (300)	190 (280)		
BCE (includes the BAPTA mtr)	60			65	65	1000	
SCU	≈20			≈7	≈7		
HEATERS MAINTENANCE WARMUP						900 1440	
MWA							2500 spinup 500 steady state

SPU - signal processing unit
BCE - BAPTA control electronics
SCU - speed control unit
MWA - momentum wheel assembly

Table 2-22 The HIMSS power subsystem voltage and current (in milliamps) requirements. In paranthesis are the values required when the 50 - 60 GHz option is included.

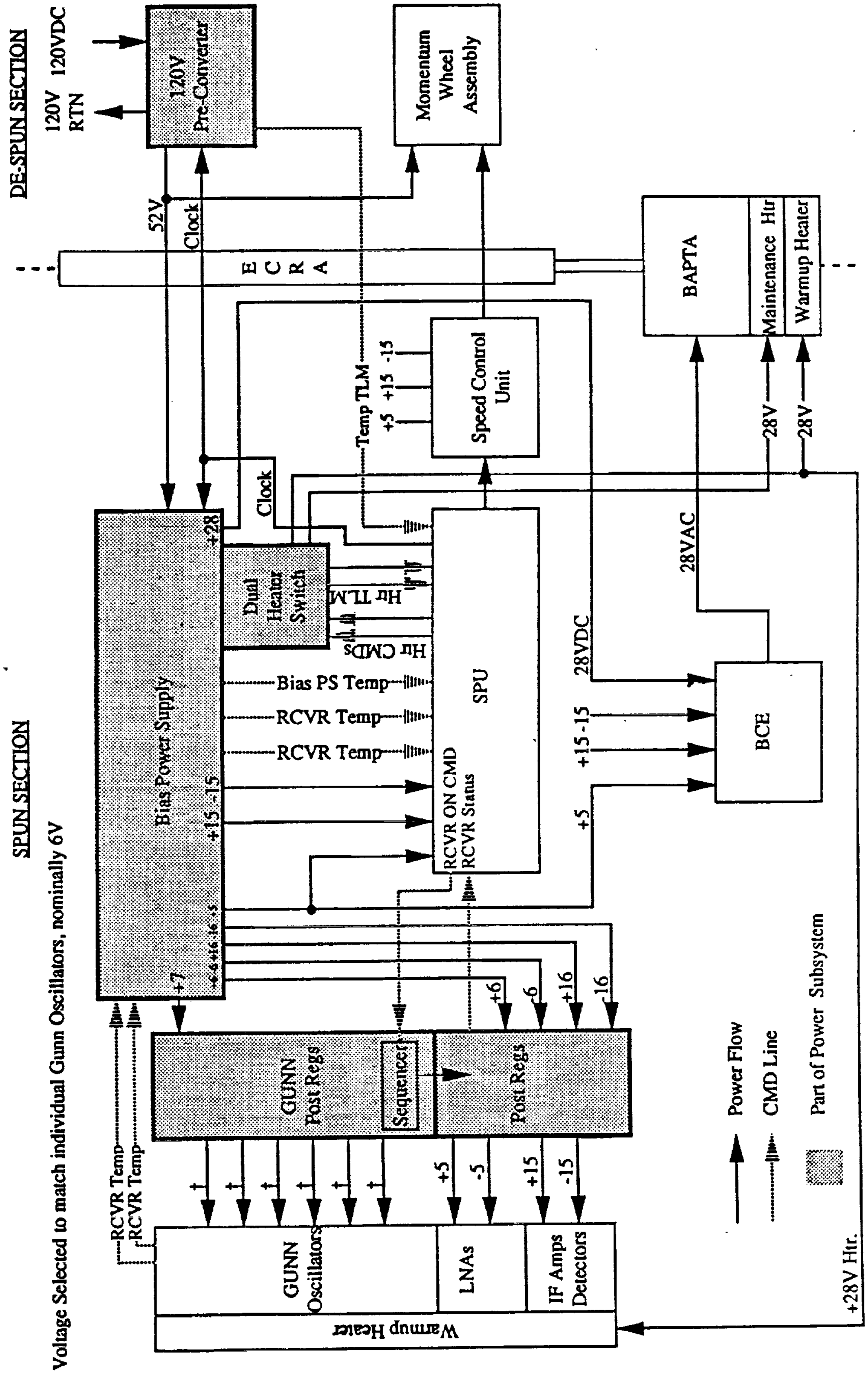


Figure 2-26. HIMSS power flow diagram.

Table 2-23. Power subsystem telemetry.
ALL TELEMETRY GOES TO THE SIGNAL PROCESSING UNIT FOR EVENTUAL DOWNLOAD IN THE SCIENCE DATA STREAM

TEMPERATURES:	PRECONVERTER
	BIAS POWER SUPPLY
	RECEIVER
STATUS:	MAINTENANCE HEATER
	WARMUP HEATER
	RECEIVER

Table 2-24. Power subsystem commands.
ALL COMMANDS COME FROM THE OBSERVATORY VIA THE SIGNAL PROCESSING UNIT

MAINTENANCE HEATER ON/OFF	PULSE TO THE BIAS POWER SUPPLY
WARMUP HEATER ON/OFF	PULSE TO THE BIAS POWER SUPPLY
RECEIVER ON/OFF	PULSE TO THE POST-REGULATORS

2.2.7.3 Design Trades

The single trade studied in the power subsystem design was the voltage to be transferred through the ECRA. The conclusion of this trade decided the architecture of the entire power subsystem. The power subsystem trade study is summarized in Table 2-25. The main feature was the voltage capability of ECRA. First of all, the flow of 120V through the ECRA was concluded not suitable. Next, the imports of 52V and/or 28V across the ECRA were studied from the point of view of technical feasibility, complexity and cost. Type I system was selected from the point of view the least modifications to the existing designs which in turn minimized cost.

2.2.7.4 Heritage

To minimize developmental cost, the bias power supply from the UHF F/O program has been selected. The power supply will have minor design modifications to match the specific HIMSS requirements of power distribution and controls. The basic design remains the same.

The post-regulators are the same design as the once used on the SSM/I program.

Table 2-25. Power subsystem trade analysis. The effects of different voltages across the ECRA on all the other HIMSS systems are compared to complexity and program cost .

Effect on:	Type I 52V Across ECRA	Type II 28V Across ECRA	Type III 52V & 28V Across ECRA (28 V across ECRA for heaters and BCE)
Power Supply Selection	Bias Power Supply: Use modified UHF F/O PS (200W); Must Supply +28 to BCE. Pre-converter: 120V->52V.	Bias Power Supply: Use modified UHF F/O PS (40W). Pre-converter: 120V -> 28V.	Bias Power Supply: Use modified UHF F/O PS (40W). Pre-converter: 120V -> 52V & 28V.
Bias Power Supply Modifications	Minor magnetics redesign for new voltages. (Bus voltage and power capability unchanged)	Major magnetics redesign to accomodate 28V input and output voltages.	Magnetics redesign for output voltages.
ECRA	Modify standoff path in ECRA for 52V(smallest ECRA change).	Higher current due to 28V may require ECRA contact changes.	At least 2 slip rings for 28 & 50 and 2 more for RTNs, major ECRA changes
BCE	Use BCE as is, minor changes for HIMSS	Use BCE as is, minor changes for HIMSS	Use BCE as is, minor changes for HIMSS
BAPTA	Use as is.	Use as is.	Use as is.
SPU	No Effect	No Effect	No Effect
RCVR	No Effect	No Effect	No Effect
MWA	Use 52V MWA	Use 28V MWA	Use 28V or 52V MWA

• Conclusion: Type I is most easily adapted to requirements.

2.2.7.5 Design

1. Preconvertor. The push-pull converter topology is a proven concept for more than 20 years in space applications. This concept provides transformer isolation between the 120V bus and the 52V bus which, in turn, minimizes noise and enhances performance reliability. The block diagram of the proposed design is shown in Figure 2-27. The monolithic integrated circuit 1825 provides current-mode control for fast loop response and high bus ripple attenuation in the range of -30 dB to -40 dB at low frequencies 30 Hz to 500 Hz. The preconverter is self protected for accidental shorts at the output during ground level testing. Use of FETs will allow switching at high frequency (384 KHz), which in turn will lead to reduction in size and weight, and to optimum efficiency.

The 120V bus necessitates the use of FETs because they are readily available for higher voltages with radiation hardening.

The preconverter shall be capable of providing 250W maximum at 52V +5%

2. Bias power supply. The bias power supply is a slightly modified existing design, modified for the specific requirements of the HIMSS power subsystem. The block diagram is shown in Figure 2-28. It consists of a switching regulator or buck converter to provide 28V for the heaters, BCE and BAPTA. There is also a DC/DC push-pull converter which provides the multiple outputs, +7V, +5V, +15V, +16V, +6V. This DC/DC converter is fed by the 28V output of the buck converter. Both converters use FETs for high frequency switching (~ 300 KHz) and can be synchronized to the external clock of 384 KHz. Self protection against accidental shorts is provided by the "pulse-by-pulse" current limit circuits. If the input voltage falls below 50% of the nominal, the power supply will turn off.

3. Post-regulators. They consist of conventional series transistor regulators to provide additional regulation. The circuit design is taken from the SSM/I program. PWB technology further offers cost reduction over MIC technology. These regulators are voltage regulators with 0 dB crossover frequency of 10 KHz to 30 KHz, thereby providing fast response times. Figure 2-29 shows the post-regulator block diagram.

A sequencer is part of the post-regulator assembly. When commanded, it injects R-C-time constants into the regulators to create time delays between the regulators so that the RF system circuits receive voltages with a prescribed sequence.

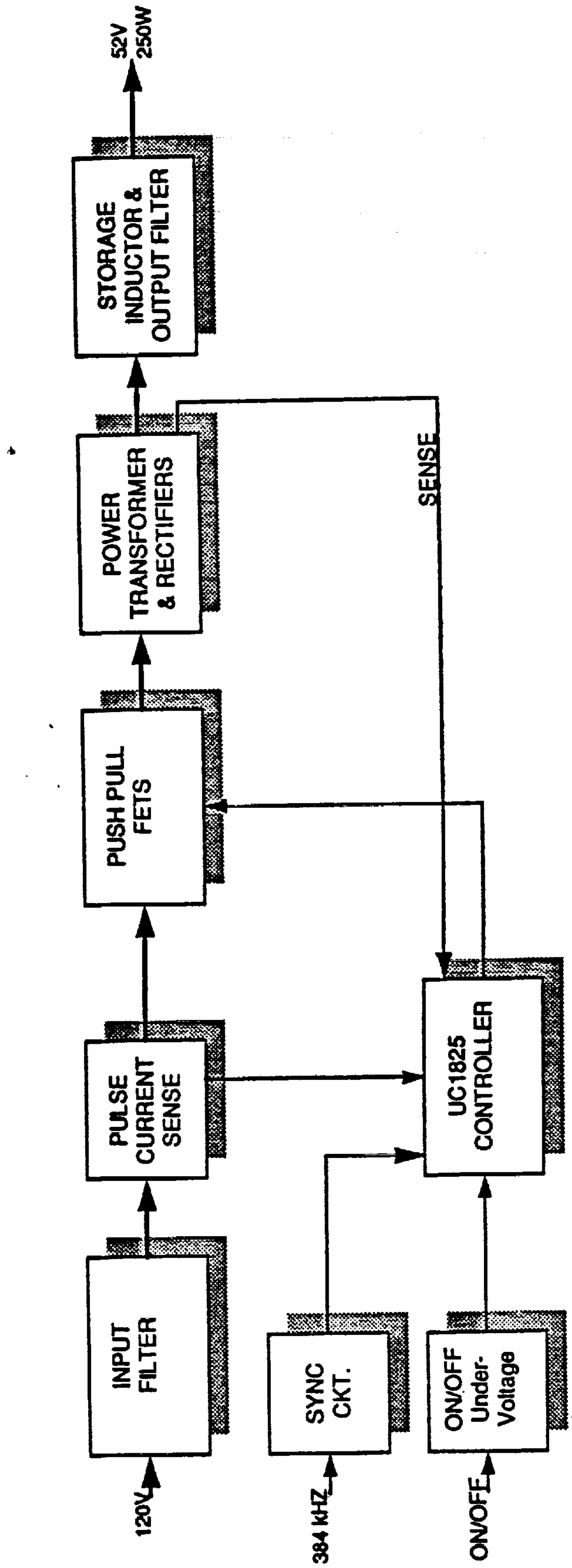


Figure 2-27. Preconverter block diagram.

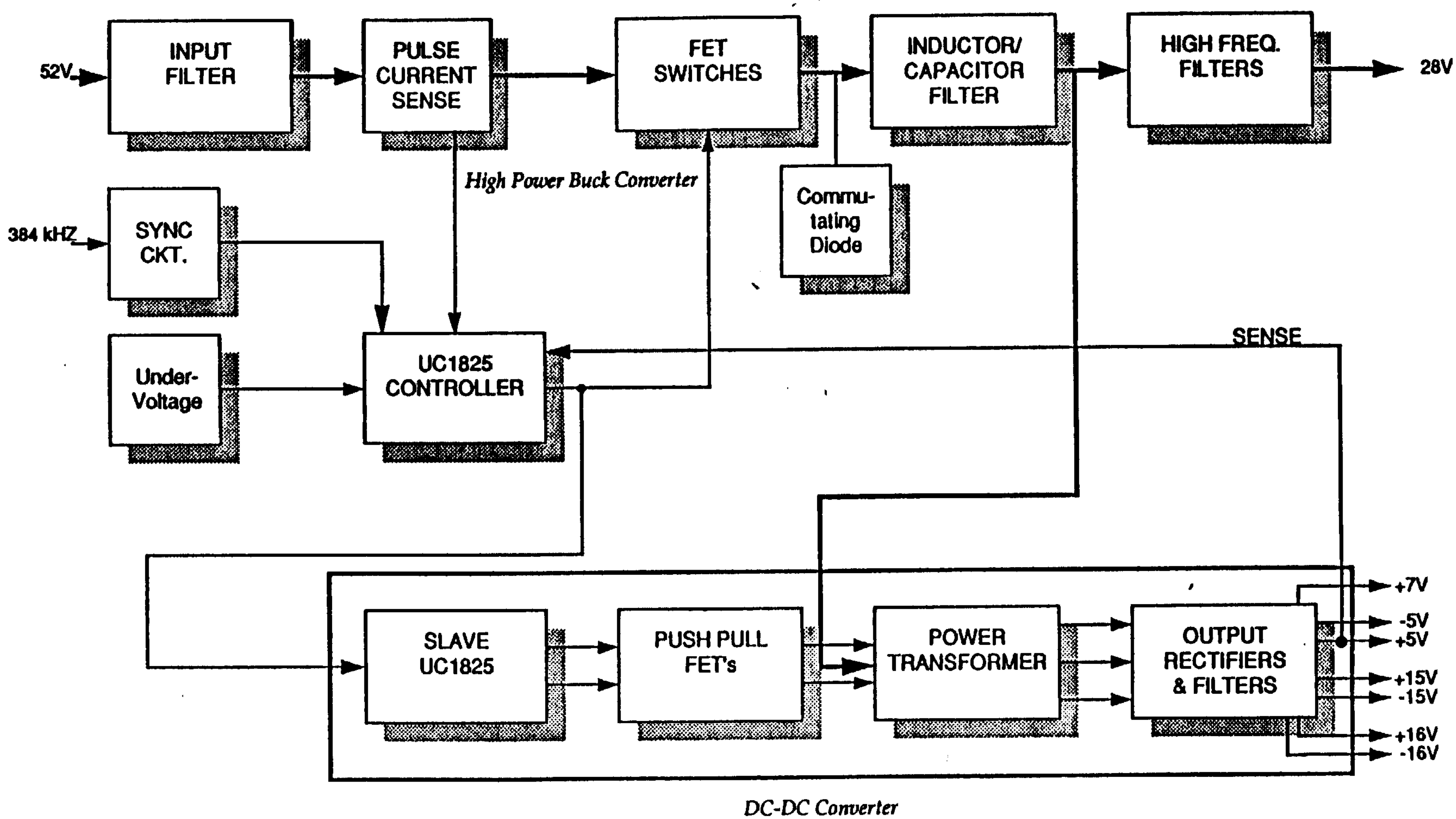


Figure 2-28. Bias power supply block diagram.

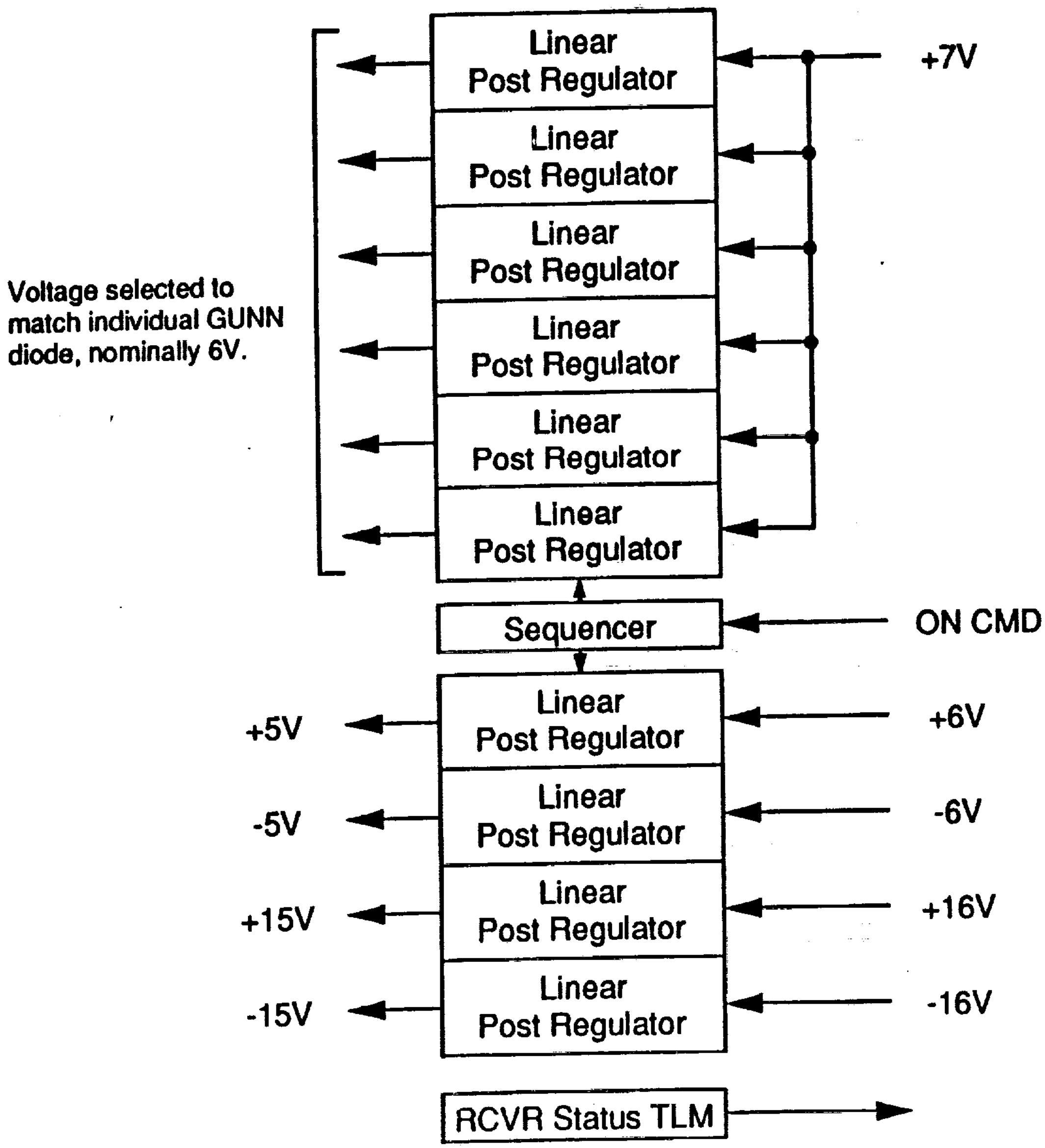


Figure 2-29. Post regulator concept. The circuit design is the same as the SSM/I post-regulators, these use PWBs.

2.3 TECHNICAL RISKS AND OFFSETS

2.3.1 MOMENTUM COMPENSATION

The spinning HIMSS instrument has associated with it a significant amount of angular momentum. The compensation of this angular momentum is an important consideration since uncompensated angular momentum can potentially impact observatory stability. The instrument's angular momentum is compensated using a momentum wheel whose angular momentum is exactly equal and opposite that of the spinning instrument. We readily meet the 0.5 N-m-sec residual angular momentum compensation requirement.

The process of compensating angular momentum involves two key areas. First, the instrument's angular momentum is analyzed and its budget tracked as the detailed instrument design evolves. Requirements for the momentum wheel assembly are developed, documented in a specification, and eventually tailored to the final requirements. In this area, Hughes will benefit significantly from its experience with momentum compensation on the SSM/I program.

Secondly, the momentum wheel assembly must be procured. The HIMSS program will use a momentum wheel developed and produced for the current generation of Hughes HS 601 satellites, thereby avoiding the complex development and qualification program which momentum wheel procurement generally involves.

The process of analyzing, specifying and tailoring the compensation of angular momentum is depicted. The key to the process is specifying the maximum angular momentum which is anticipated. We have determined that the HS 601 wheel is more than adequate to compensate the angular momentum of the HIMSS instrument. The final angular momentum of the MWA is set during the final stages of integration by decreasing the rotation rate of the momentum wheel to exactly compensate the angular momentum of the fabricated HIMSS instrument. This adjustment is achieved with the speed control unit.

2.3.2 TORQUE DISTURBANCE

Numerous instruments on the Eos observatory require a very stable platform for their proper functioning. The stringent torque disturbance specification of Appendix A of the HIMSS Definition Study statement of work requires both passive and active balancing methodologies.

Passive balancing involves the spin-balancing of the instrument during the final stages of instrument integration through the placement of small weights at the appropriate points on the instrument. Analysis estimating the static and dynamic imbalance are discussed below.

Active balancing is performed in-orbit and involves commanded movement of weights on the instrument. The estimated imbalance, when using active balancing, provides an order of magnitude of margin.

2.3.2.1 Static Imbalance Analysis

A detailed static imbalance budget, based on the experience with SSM/I, is presented in Table 2-26. Static balancing alone can result in an estimated 0.0053 Kg-m imbalance versus the requirement of 0.00[illegible]4 Kg-m.

In order to meet the requirement, in-orbit active balancing will be employed.

The sources of static imbalance are tabulated along with the corresponding values for SSM/I S/N 005 and the current HIMSS design. Several of the SSM/I values are simply conservative upper bounds rather than actual measurements or analytical predictions.

The ground balancing process on SSM/I is terminated when the mean of the imbalance measurements, taken with the SSM/I sensor clocked on its despin bearing to several locations around 360 degrees is less than 0.1 in-lbm. The 3-sigma variation about this mean value is typically 0.08 in-lbm. When the measurement process residual errors are combined with the above estimated uncertainty, the net HIMSS on orbit deployed static imbalance is estimated to be 0.1 +/- 0.364 in-lbm or a maximum value of 0.464 in-lbm (0.00538 Kg-m).

2.3.2.2 Dynamic Imbalance Analysis

The detailed dynamic imbalance budget is presented in Table 2-27. Dynamic balancing alone exactly meets the requirement of 0.0059 Kg-m^2. In order to provide margin relative to the dynamic imbalance requirement, active balancing is again indicated.

The sources of sensor dynamic imbalance are tabulated here along with the corresponding values for SSM/I S/N 005 and the current HIMSS design. The largest contributor to dynamic imbalance uncertainty is deployment repeatability, which is estimated at 14.8 lbm-in^2 for the larger HIMSS reflector. The maximum on orbit deployed dynamic imbalance is 20 lbm-in^2 (0.0059 Kg-m^2), based on maximum uncertainty and measurement errors.

2.3.2.3 Active Balancing Methodology

Active on orbit balancing using a set of commandable mass balance mechanisms has been applied to several Hughes spacecraft, including the Geosynchronous Meteorological Satellite (GMS) and two other Hughes satellites, HS 333 and HS 350.

Two balance mechanisms are mounted perpendicular to one another on the spinning instrument in the plane of its center of gravity. Each mechanism has a weight which can be commanded to various positions by a stepper motor. The design includes a Y-axis linear accelerometer for sensing observatory jitter at spin frequency.

The output of the force re-balance type servo accelerometer is bandpass filtered and telemetered the ground. The screw driven mass balance weights are then driven in turn by ground command to reduce the magnitude of the sensed acceleration at spin frequency. Given the increments of adjustment available (0.01 in-lb resolution), the HIMSS contribution to observatory jitter is less than the allocated 0.2 arcseconds.

Table 2-26. Static imbalance analysis and budget.

SOURCE	STATIC IMBALANCE (IN-LB) SSM/I SN 005	HIMSS DESIGN*	HIMSS RATIONALE
MRC READOUT ERROR	0.330	0.100	MRC SPEC.
BEARING RUNOUT	0.291	0.060	2 ARC SEC. CONING 0.0003 in. BEARING PLAY
TILT & ECCENTRICITY	0.201	N/A	ELIMINATED BY CLOCKING BAPTA DURING BALANCING
GATE LINK LOCATION	0.021	0.021	
WATER LOSS IN ORBIT	0.031	0.062	2X SSM/I VALUE(TBD)
GRAVITY EFFECT	0.003	0.090	.003 in. REFLECTOR OFFLOAD ERROR ESTIMATE
DEPLOYMENT REPEATABILITY	0.156	0.148	0.01° HINGE REPEATABLILTY
THERMAL BLANKET INSTALLATION	0.140	0.280	2X SSM/I VALUE(TBD)
I) RSS OF UNCERTAINTIES	±0.529	±0.355	
II) 3σ MEASUREMENT VARIATION	±0.08	±0.08	SSM/I VALUE(TBD)
II) RSS OF I & II	±0.535	±0.364	
IV) STATIC IMBALANCE (MEASURED)	±0.1	±0.1	SSM/I VALUE(TBD)
V) TOTAL STATIC IMBALANCE	0.1±0.535	0.1±0.364	
VI) WEIGHT OF SENSOR, LB	85	209	
MAXIMUM STATIC OFFSET, IN (V/VI)	0.0075	0.0022	*(11/27/89 update)
SPECIFIED STATIC OFFSET,IN	0.013	TBD	

Table 2-27. Dynamic imbalance analysis and budget.

SOURCE	DYNAMIC IMBALANCE (LB-IN^2) SSM/I SN 005	HIMSS DESIGN*	HIMSS RATIONALE
BEARING RUNOUT	2.45	2.10	2 ARC SEC. CONING 0.0003 in. BEARING PLAY
TILT & ECCENTRICITY	2.51	N/A	ELIMINATED BY CLOCKING BAPTA DURING BALANCING
GATE LINK LOCATION	0.26	0.26	
WATER LOSS IN ORBIT	0.61	2.4	4X SSM/I VALUE(TBD)
GRAVITY EFFECT	0.06	8.60	.003 in. REFLECTOR OFFLOAD ERROR ESTIMATE
DEPLOYMENT REPEATABILITY	3.53	14.8	0.01° HINGE REPEATABLILTY
THERMAL BLANKET INSTALLATION	0.61	2.4	4X SSM/I VALUE(TBD)
BALANCE WEIGHT INSTALLATION	1.00	4.0	4X SSM/I VALUE(TBD)
I) RSS OF UNCERTAINTIES	±5.16	±18.03	
II) 3σ MEASUREMENT VARIATION	±3.67	±3.67	SSM/I VALUE(TBD)
III) RSS OF I & II	±6.33	±18.4	
IV) DYNAMIC IMBALANCE (MEASURED)	1.54	1.54	SSM/I VALUE(TBD)
V) TOTAL DYNAMIC IMBALANCE	1.54±6.33	1.54±18.4	(0.0059 kg m^2 max)
MAXIMUM DYNAMIC IMBALANCE, LB-IN^2 (KG-M^2)	7.87 (0.0023)	20.0 (0.0059)	*(11/28/89 update)
SPECIFIED DYNAMIC IMBALANCE, LB-IN^2	12	TBD	

2.3.3 BAPTA

The BAPTA provides the spin mechanism (whereby the instrument rotates) and the slip rings for transfer of the power, data, telemetry and commands.

Hughes is in a unique position within the aerospace industry, having unparalleled experience with space qualified BAPTAs. Beginning with Syncom I, the first spin-stabilized communications satellite, Hughes has gained 27 years experience with BAPTAs. In these 27 years, involving hundreds of satellites, some with as much as 15 years operating life in-orbit, the BAPTA has never failed.

Because of the sensitivity of almost all spacecraft to contamination, the BAPTA employs a special low outgassing lubricant. To further reduce the potential for contamination, the BAPTA is designed with a tortuous venting path from the lubricant containing region.

2.3.4 CALIBRATION TECHNIQUES

As mentioned earlier, HIMSS is a mechanically scanning radiometer. This architecture provides more accurate instrument calibration on orbit. During each scan period, RF energy from the warm and cold loads passes through the same feedhorns and receiver paths as the science data sensed from the earth. This provides direct calibration data for the instrument, and no switches or secondary references are required.

This calibration approach, resulting from the mechanically scanning instrument architecture, represents a major advantage over electrically scanned instruments, whose calibration data must be provided indirectly.

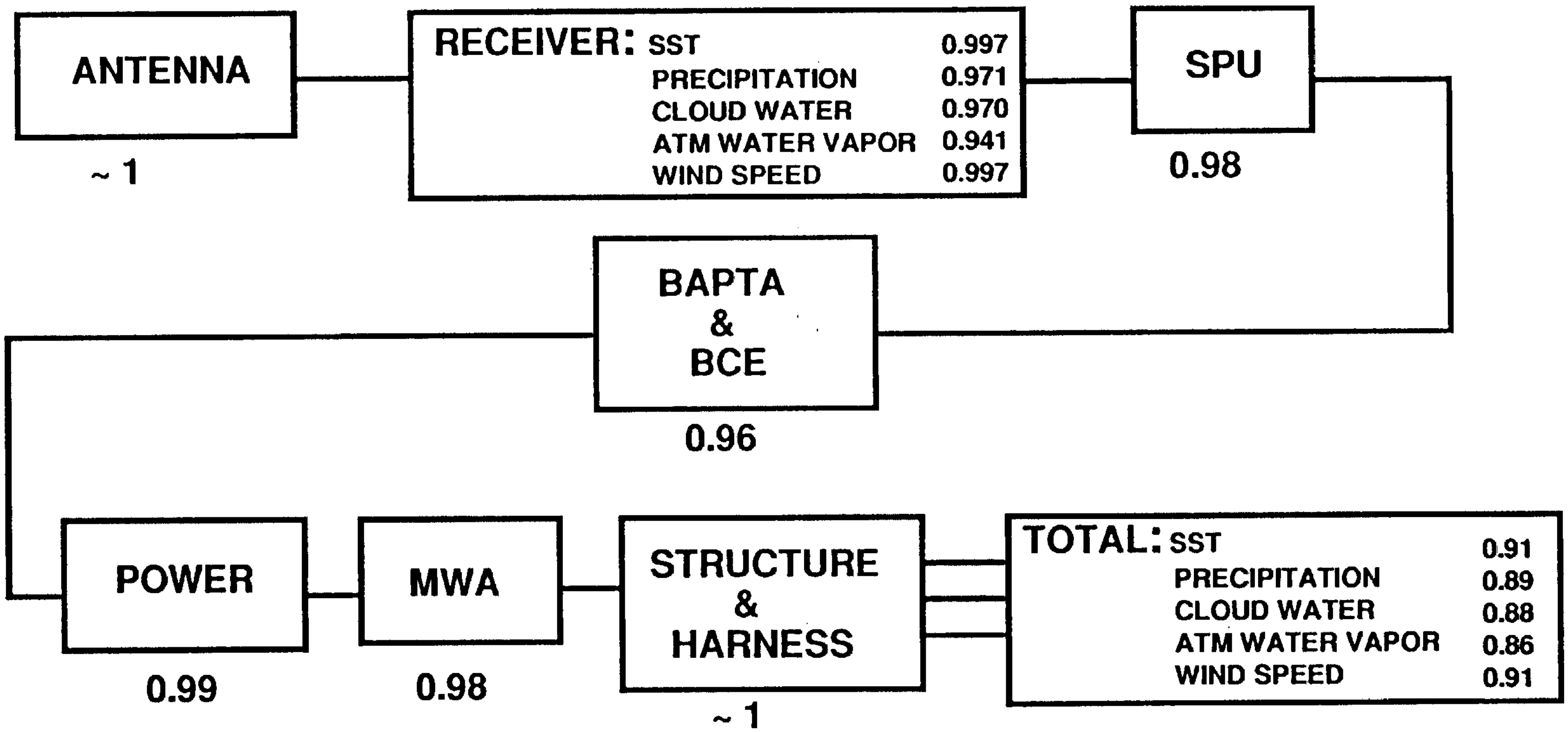
Ground tests performed on the antenna test range provide the coefficients required for the algorithms for antenna pattern correction. Testing in thermal vacuum proves the linearuty of each channel. Instrument performance is validated through a rigorous calibration-validation program which Hughes will support. Science data from the HIMSS instrument will be compared directly to ground based observations.

2.4 INSTRUMENT RELIABILITY

Figure 2-30 shows the calculated reliability estimated from a preliminary listing of components. MIL STD 417E, Notice 1 has been used for failure rates. The calculations have been made for each of the different parameters to be retrieved.

The reliability varies depending on the number and the type of receiver channels needed for the retrieval. For example, sea surface temperature retrieval requires only one of the 6 GHz channels to be operating. There are six 6 GHz channels on-board the HIMSS. So, the reliability that any one of these will be operating is very high (0.997). The overall instrument reliability for that parameter is 0.91.

Sea surface temperature, precipitation, cloud water, atmospheric water vapor, and sea surface roughness from which wind speed is calculated, have been identified as critical science parameters. The reliability figure associated with each of the critical parameters meets the requirement of 0.7 over 5 years as well as the goal of 0.85 over 5 years.



BAPTA : BEARING AND POWER TRANSFER ASSEMBLY
BCE : BAPTA CONTROL ELECTRONICS
MWA : MOMENTUM WHEEL ASSEMBLY

SPU : SIGNAL PROCESSING UNIT
SST : SEA SURFACE TEMPERATURE

Figure 2-30. Estimated reliability for the HIMSS units and for the overall retrieval of some environmental parameters.

2.5 COMMANDS AND TELEMETRY

Table 2-32 lists the commands in the order in which they are applied. The routing of the commands is shown along with the action resulting from the command.

Table 2-33 lists the telemetry generated by the instrument and sent to the standard interface connector (SIC) in the science data stream.

The BAPTA temperature is a critical parameter which will be sent to the spacecraft as an alarm telemetry point. If the BAPTA temperature exceeds its maximum operational temperature (+38 degrees C) the sensor should be spun down.

The conditioning of the telemetry circuits and the hybrid for the antenna angle and the warm loads temperatures reside in the signal processing subsystem.

Table 2-32. HIMSS sequence of commands

COMMAND TYPE	COMMAND NAME	ROUTING	RESULT
VOLTAGE APPLICATION	ANTENNA PYRO FIRING	ANTENNA PYROS	ANTENNA DEPLOYMENT
VOLTAGE APPLICATION	MARMAN CLAMP PYRO FIRING	MARMAN CLAMP PYROS	BAPTA RELEASE
VOLTAGE APPLICATION	POWER ENABLE	PRE-CONVERTER	POWER TO SPU , BCE & MWA
PULSE	MWA ENABLE	MWA	MWA IS TURNED ON
SERIAL	WARM-UP HTR ON MAINTENANCE HTR ON	SPU → BIAS PS	POWER TO BAPTA AND RECEIVER COMPARTMENT HTRS
SERIAL	MOTOR DRIVER ON REF CLOCK ON	SPU → BCE SCU	ENABLES BAPTA MOTOR DRIVER MW STARTS SPINNING
SERIAL	WARM-UP HTR OFF RECEIVERS ON	SPU → BIAS PS	DATA TO S/C

BCE : BAPTA CONTROL ELECTRONICS
MWA : MOMENTUM WHEEL ASSEMBLY
PS : POWER SUPPLY
SCU : SPEED CONTROL UNIT
SPU : SIGNAL PROCESSING UNIT

Table 2-33. HIMSS telemetry

TELEMETRY	SOURCE	TYPE	FUNCTION
MOTOR ON WARM-UP HTR ON MAINTENANCE HTR ON RECEIVERS ON	BCE BIAS PS	DIGITAL	VERIFIES COMMANDS
TEMPERATURES: SPU BCE PS (2) REC (2) BAPTA *	SPU BCE PRE-CONVERTER & BIAS PS RECEIVER BAPTA MTR	ANALOG	UNIT TEMPERATURE
MOMENTUM UNBALANCE	BCE	ANALOG	DELTA (MW RATE AND BAPTA MOTOR SPEED)
ANT DEPLOYMENT ANGLE **	DEPLOY MECH	ANALOG	REFLECTOR ANGLE
WARM LOAD TEMPERATURE(6) **	WARM LOADS	ANALOG	CALIBRATION TEMPERATURE

* TELEMETRY SENT TO S/C
** CONDITIONING DONE BY THE SPU

ANT : ANTENNA REFLECTOR
BAPTA : BEARING AND POWER TRANSFER ASSEMBLY
BCE : BAPTA CONTROL ELECTRONICS
MW : MOMENTUM WHEEL
SPU : SIGNAL PROCESSING UNIT

2.6 MASS AND POWER BUDGETS

The overall mass of the HIMSS instrument, including the payload support structure, is 210 Kg. This value includes a 30% contingency. Even with this high percentage as contingency, the instrument still has more than 5% positive margin.

The power consumed by HIMSS is 124 Watts. This number includes a 20% contingency.

Table 2-34 shows the mass and power budgets for the baseline design and the design including the 50-60 GHz channels option.

Table 2-34. Mass and power budgets, including the 50 - 60 GHz option impact.

	MASS, Kg			POWER, Watts	
	BASELINE		OPTION	BASELINE	OPTION
	SPUN	DESPUN			
ANTENNA SUBSYSTEM	15	5.5		–	
RECEIVER SUBSYSTEM	11.5		+2.4	30.5	+7.9
SIGNAL PROCESSING SUBSYSTEM	2			8.3	+1.1
STRUCTURES AND MECHANISMS	45.5			–	
BAPTA AND BCE	6.5	5		5.5*	
MOMENTUM WHEEL(INCLUDING SCU)	1	11.5		25*	
				69.3	78.3
POWER SUBSYSTEM (EFF. 67%)	2.5	1.5		34.1	38.6
SUBTOTAL	84	23.5		103.4	116.9
SUBTOTAL EXCLUDING PSS	107.5		109.9		
PAYLOAD SUPPORT STRUCTURE (PSS)	54				
HIMSS TOTAL	161.5		163.9	103.4	116.9
WITH CONTINGENCY	210 (30%)		213	124 (20%)	140.3
SPECIFICATION	222			85**	

* STEADY STATE POWER CONSUMPTION
** IN THE AO PROPOSAL

2.7 INTEGRATION AND TEST PROGRAM

2.7.1 OVERVIEW

The entire integration and test program is shown in Figure 2-31. The antenna subsystem range test and electrical assembly test occur before the final integration of the sensor. Most of the antenna subsystem will be assembled for the range test, where the main and cold sky reflectors are aligned to the feedhorn array, and then tested for their performance. Most of the electronic equipment will be installed on a test plate for an electrical assembly test, which verifies performance at ambient and at the temperature extremes. The sensor is then integrated. Magnetic compensation, spin balance/mass properties and momentum compensation are performed on the full-up sensor.

System tests are a series of environmental tests performed on the sensor in different configurations. The main reflector is installed for all but the thermal vacuum (TV) test. In TV the main reflector and the cold sky reflector are replaced by specially built targets. For vibration and pyroshock the full-up sensor will be in the stowed configuration, simulating launch conditions.

The second and third instruments are acceptance tested, and do not go through EMC, pyroshock and thermal balance tests. The acceptance thermal limits are 10 degrees less severe than the qualification thermal limits of -10° (TBR) and +40° (TBR) C.

Details of the test program are found in the Verification Plan, section 4.7.

2.7.1.1 Antenna Subsystem Range Test

The objectives of this test are to align the main and cold sky reflectors to the feedhorn array,and to verify compliance with the antenna subsystem specification. The main reflector is mounted on the top ring of the sensor, using a fixture that offsets the gravity

effects during the data gathering. The feedhorn array is supported in its mounting assembly. Once the alignment is completed and the reflectors and the feedhorn array are adjusted for best electrical performance, the feedhorn array is not removed from its assembly again

2.7.1.2 Electrical Assembly Test

The electrical assembly test verifies the performance of the receivers and the SPU before they are integrated in the sensor. The test items are installed on a test plate, so that all are easily accessible. This setup undergoes a baseline full functional test (FFT), followed by 6 thermal cycles, during which limited functional tests (LFT) are run, and then a final FFT to assure that the thermal cycling has not changed the electrical assembly's performance. Two important parameters, checked in each FFT are the receiver's noise figure and the radiometer Delta T. These data will serve as a baseline for all the remaining tests.

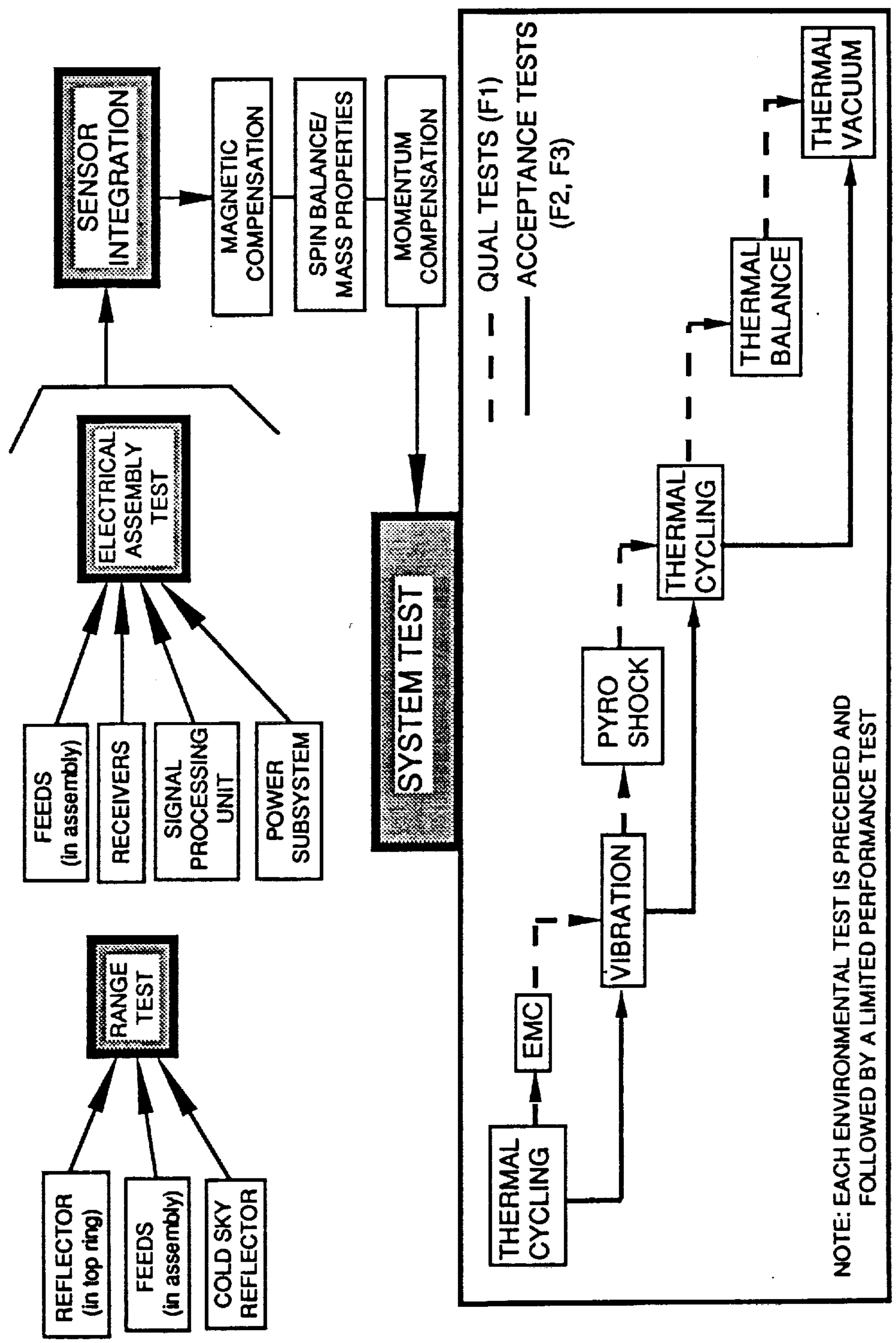


Figure 2-31. Integration and test program.

2.7.2 INSTRUMENT INTEGRATION

In parallel with the subsystem tests, integration starts with the BAPTA installation and its alignment to the payload support plate (PSP), Figure 2-32.. The despun wiring harness is connected to the ECRA and the Marman clamp is installed. The electrical assembly units and the remaining electronics are then mounted on the spun structure. Before the spun structure is closed, the spun harness is connected to the ECRA. At this point the reflector and the loads are integrated. The completed sensor goes through magnetic compensation, spin balance and mass properties tests and then its momentum is measured. Once all these tasks are completed, the sensor is installed on the payload support structure (PSS) along with the momentum wheel assembly (MWA) and the pre-converter. The payload integrator units, the BSR and the BDU, are installed on the PSS for a fit check before the sensor, preconverter, and MWA enter system tests.

2.7.3 SYSTEM TEST

The objective of system test is to verify performance in all environments and show compliance with all instrument specifications. The system test sequence for the protoflight model, F1 is as follows:

a) EMI/EMC
b) Thermal cycling - 4 cycles
c) Pyroshock
d) Vibration
e) Thermal cycling - 4 cycles
f) Thermal balance
g) Thermal vacuum/calibration

The EMI/EMC, pyroshock, and thermal balance tests are deleted for the subsequent instruments.

Throughout the course of system test, trend analysis is performed by monitoring the noise figure, radiometer Delta T and power consumption data, and comparing these data with earlier measurements.

2.7.3.1Qualification Test Sequence - Protoflight Instrument F1

The qualification test sequence is shown in detail in Figure 2-33. Comprehensive performance tests (CPT) are performed at the start, before the thermal balance test (or TV, in the acceptance test sequence) and at the end, after the sensor has completed TV. Limited performance tests (LPT) are performed between the different tests and/or after transportation between facilities. The thermal cycling is divided into two phases so that any problems caused by the vibration and pyroshock tests will be exposed in the second set of thermal cycles. The last environment in system test is thermal vacuum. The sensor, with targets replacing the main and the cold sky reflectors, is exposed to 4 thermal cycles in a vacuum environment while it is spinning. Calibration coefficients for all sensor telemetry are obtained in the last TV cycle.

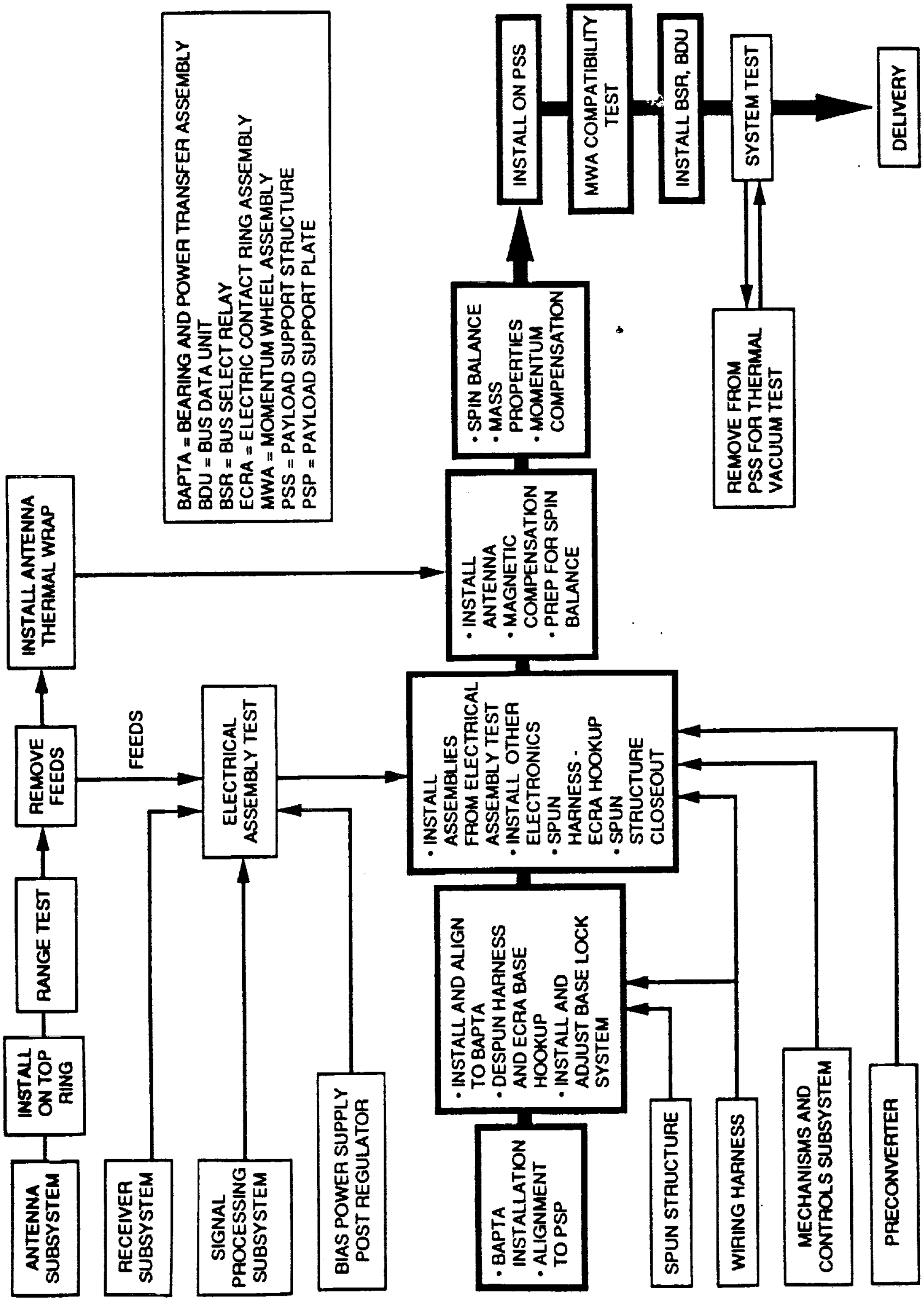
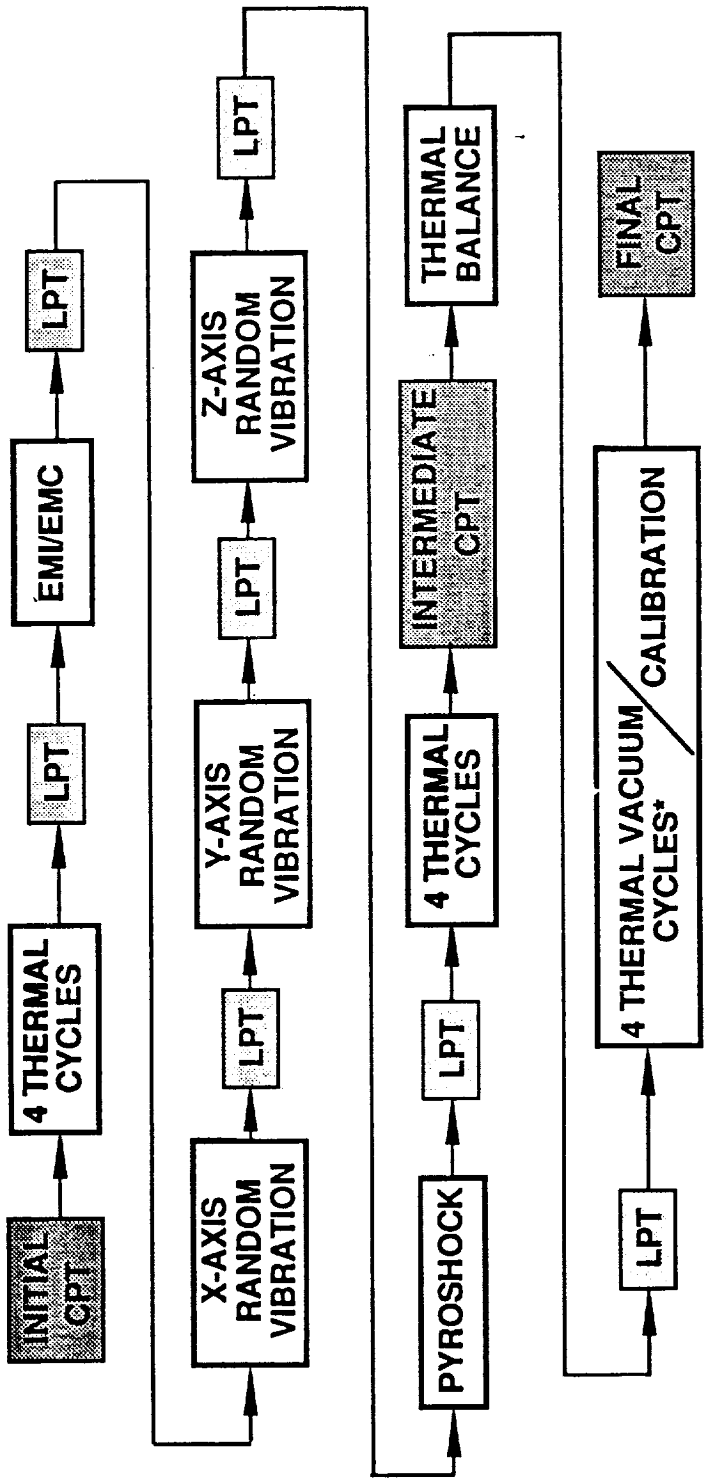


Figure 2-32. Detailed integration flow.



*A LPT IS PERFORED AT EACH TEMPERATURE EXTREME

CPT: COMPREHENSIVE PERFORMANCE TEST
LPT: LIMITED PERFORMANCE TEST

Figure 2-33. Qualification test sequence.

2.7.3.2 Acceptance Test Sequence- Instruments F2 and F3

This test sequence is a subset of the qualification test sequence. The vibration levels are lower than in the qualification test, and the EMI/EMC, pyroshock, and thermal balance tests are eliminated.

3.1 PROGRAM IMPLEMENTATION

The development, production, and test activities are part of a structured methodology, documented in the various program plans, which assures that all HIMSS objectives are achieved and that each of the program requirements is adequately addressed and satisfied. The HIMSS program comprises two key elements, development and production. Intermediate milestones and objectives are defined to facilitate the successful completion of the program.

The development program begins at contract go-ahead with requirements definition and allocation and continues through proof of design testing and successful completion of the Critical Design Review (CDR) in October, 1993 and of the demonstration tests at GE in November, 1993. Other major milestones within the development program include the Preliminary Requirements Review (PRR), the Preliminary Design Review (PDR), and the demonstration tests at Hughes.

Shortly after CDR, a Manufacturing Readiness Review (MRR) is conducted and the production program begins. A key feature of the overall HIMSS program is the ongoing coordination between the design, manufacturing, and test organizations to assure the formulation of a manufacturable and producible design.

3.1.1 DEVELOPMENT PROGRAM

The development program is structured to achieve a systematic progression of the design from the present conceptual architecture to a fully qualified protoflight instrument (F1).

Development of the HIMSS instrument proceeds according to the HIMSS Program Implementation Plan. The design is proven through analysis and modeling, complemented by rigorous testing at each successive level of hardware evolution: breadboard units, engineering model units, and the protoflight qualification instrument.

System engineering provides direction and control for the development, process, They guide initial interface definition and flowdown of the requirements. They also coordinate the interaction among design engineering, manufacturing, and test to ensure a manufacturable and producible design.

Design reviews are held as the program proceeds through its various phases. Open requirements are defined or dates set for their definition at the PRR. The PDR presents the flowdown of system level requirements and provides design concepts which satisfy these requirements, accompanied by estimates of HIMSS instrument performance. The CDR demonstrates the adequacy of the design to comply with allocated requirements. Detailed subsystem and unit designs are presented, along with analytical results and demonstration test data.

Figure 3-1 illustrates the flow of the development program.

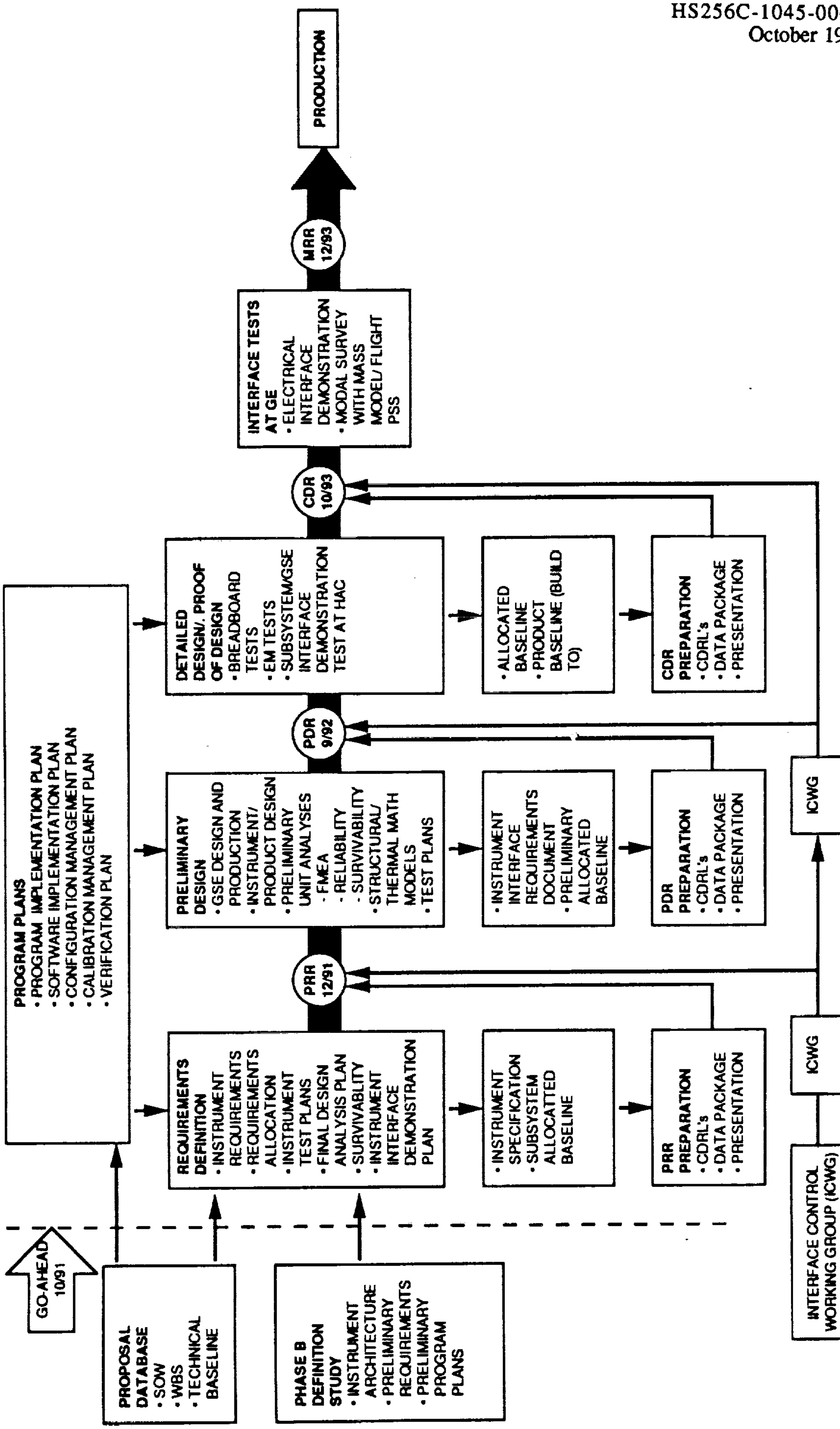


Figure 3-1. The development program flow shows the progression of the various phases in the instrument development

3.1.1.1 Subsystem Interface Test at Hughes

The adequacy of the engineering design will be demonstrated during an electrical assembly demonstration test at Hughes.

Engineering models of a feedhorn, receiver, power supply and SPU will be used for this demonstration. This hardware will be integrated and tested to demonstrate the proper functioning of the electrical interfaces between the various HIMSS subsystems.

3.1.1.2 Interface Demonstration at GE

Following successful completion of the electrical assembly demonstration test at Hughes, the signal processing unit (SPU) will be taken to GE and integrated with the observatory bus data unit (BDU) and the standard interface connector (SIC). Successful completion of this test will demonstrate the compatibility and proper functioning of the SPU with the BDU, from which the SPU receives commands and to which it passes alarm telemetry, and the SIC, to which it sends science data.

3.1.2 INSTRUMENT PRODUCTION PROGRAM

The production program defines the methodology for the entire process from producibility activities during the design phase, through procurement and planning document preparation, to fabrication, assembly, integration, and test. The production program encompasses numerous lower level plans such as the manufacturing plan and the qualification and acceptance test plans and procedures, as well as the many company and group practices relating to production activities.

The HIMSS manufacturing plan, Figure 3-2, addresses all phases of manufacturing and assures that all requirements are met with the most cost-effective design. The manufacturing managements system that implements the plan is consistent with Hughes command media, which reflect the requirements of MIL-STD-1528.

SCG's organization itself contributes to cost-effective manufacturing. For the HIMSS program, each subsystem will have a dedicated team working on program hardware within a focussed facility. The stores, assembly, test, and quality control operations for each product line located within one area.

An important element of the production process is planning package preparation. The planning package documents the step-by-step operations of assembly and test. It includes kit requisition and traceability records (KRTR), as-built configurations, quality control history records (QCHR), process records, and rework documentation. The planner prepares the planning package from the information which he receives from the engineering drawing, from the program quality requirements (PQR) document, and from division quality instructions.

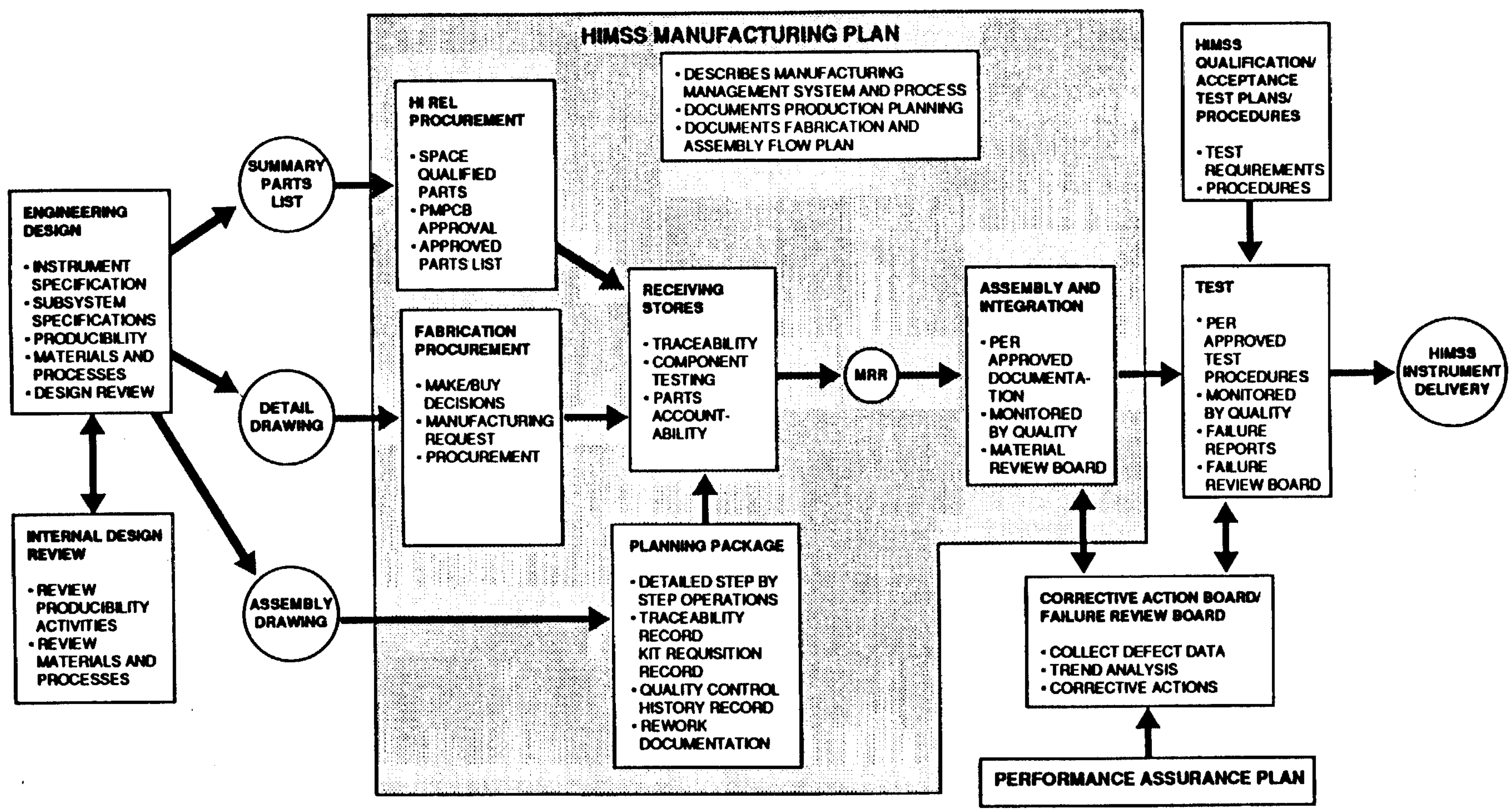


Figure 3-2. The production program addresses all phases of manufacturing and assures a cost-effective program.

3.2 PHASE CD SCHEDULE

The master schedule for the HIMSS program provides for delivery of the first flight instrument in December, 1995 based on contract award in October, 1991. This schedule, Figure 3-3, supports the planned December, 1997 launch of the Eos-A observatory.

The schedule presented includes both the development and production phases of the program. The schedule reflects our emphasis on early and detailed definition of requirements, followed by the systematic allocation and flowdown of requirements to the subsystem and unit levels. Delivery dates for significant documents are shown.

Design reviews are scheduled to assure that each phase of development has been successfully completed before the next phase begins. We plan for three major design reviews, the Preliminary Requirements Review (PRR), the Preliminary Design Review (PDR), and the Critical Design Review (CDR). We have also scheduled a Manufacturing Readiness Review (MRR) to assure that all manufacturing documentation is satisfactorily completed prior to the start of subsystem assembly.

Two major milestones in the HIMSS development program are the electrical interface demonstration tests at Hughes and at the payload integrator's facility. The first of these tests will demonstrate the adequacy of all electrical interfaces between HIMSS subsystems and the instrument level test equipment. The test at GE will demonstrate that the signal processing subsystem interfaces properly with the observatory's bus data unit (BDU) and standard interface connector (SIC).

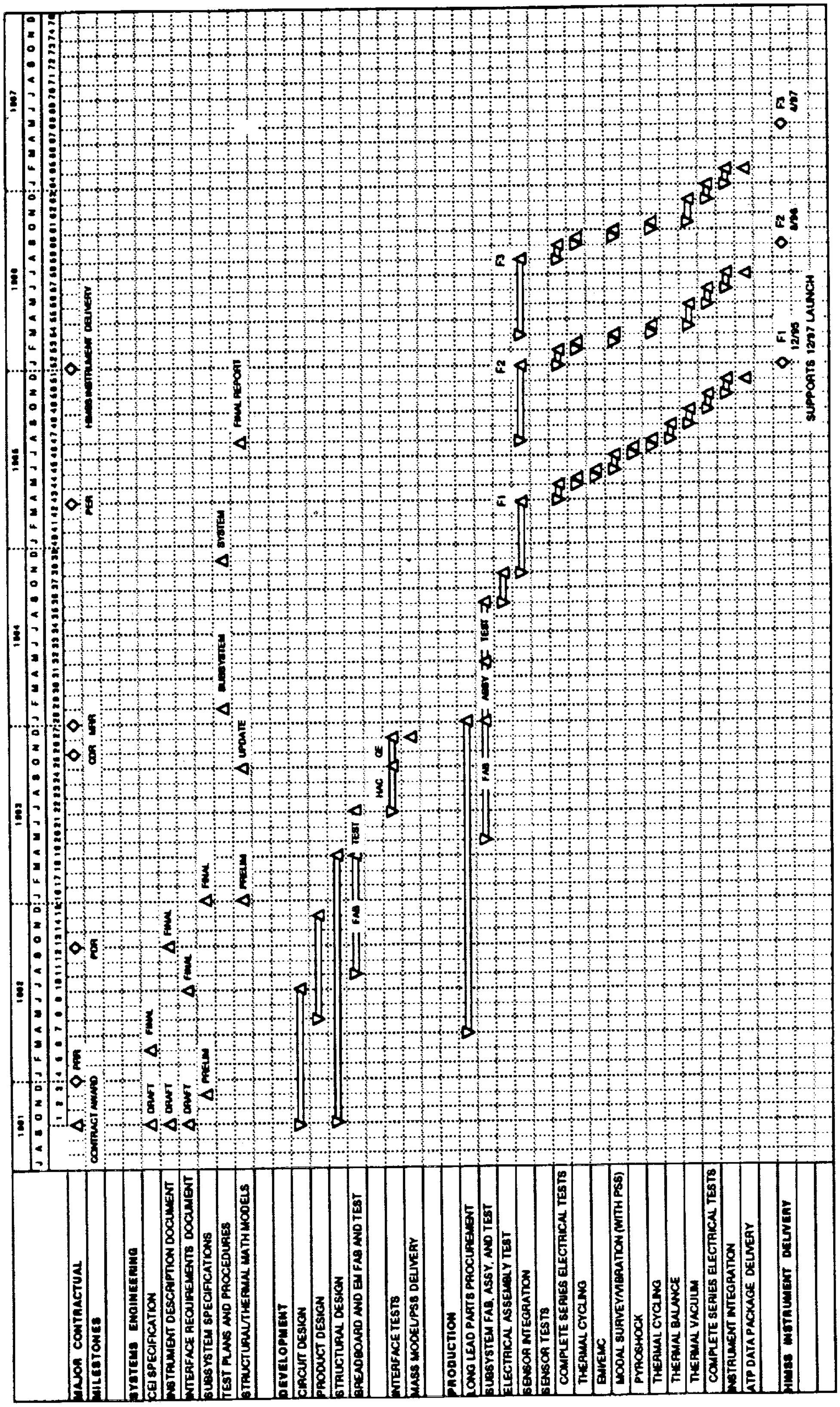


Figure 3-3. This master schedule supports all the planned launches of the Eos observatories.